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PROFESSOR HART's approach to his subject is quiet and sober, but the subject itself is so sensational and of such immediate interest that this type of realistic treatment only serves to enhance its drama. Opening the book almost at random the reader will immediately become absorbed by one of the intriguing episodes from the history of medicine with which it abounds.

POMP AND PESTILENCE

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Infectious Disease, Its Origins and Conquest

by

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CHAPTER ONE

PARASITES AND PARASITISM

So, naturalists observe, a flea
Has smaller fleas that on him prey;
And these have smaller still to bite 'em;
And so proceed *ad infinitum*.

SWIFT: *Poetry, a Rhapsody.*

IT SEEMS PROBABLE that Man has taken about half a million years to develop to his present bodily and mental stature. During the last 5,000 years or so, he has been afflicted by many forms of infectious disease, which has undoubtedly served to limit the natural increase in the population, and on occasions has even come near to exterminating him. The probable origins of diseases of such potentialities are therefore matters of more than passing interest in any review of the human race. Hitherto, little has been written about this problem, but within the past few decades so much has been learned about the agents which cause these diseases, and about the habits and customs of Primitive Man himself, that something more than mere speculation may now be attempted.

Of equal interest, and probably of greater importance, is the process by which Man has gradually learned to control these infections. To such an extent is this now possible that many of them can be completely exterminated. In others the severity of an attack can be greatly lessened and, in many instances, death can certainly be prevented. As yet, this kind of interference with the course of Nature has

hardly had time to make itself felt, but there can be no doubt that the virtual elimination of infectious diseases as a cause of death and disablement will bring a host of serious problems in its train.

Both the origin and conquest of infectious disease are, therefore, themes of some importance in the world to-day.

Most of us, if asked for examples of an infectious disease, would probably mention measles, smallpox, scarlet fever, chicken-pox, mumps and diphtheria, because it is a matter of common knowledge that susceptible individuals in contact with patients suffering from these diseases will generally become infected in their turn. Few of us, however, would venture to suggest that pneumonia, malaria, hookworm infection, and infections of wounds were infectious diseases. Nevertheless, there is now abundant evidence that they are the result of the same fundamental process as occurs in all the more obviously infectious diseases: that is, the transmission of a living agent from a patient with the disease to someone who has hitherto been without it. Nor need we limit the term "infectious disease" to disease acquired from human beings, for a minority of infections of this type may be acquired from animals.

But infectious disease must not be confused with contagious disease. The latter is a particular variety of infectious disease: that is to say, a disease which is generally acquired as a result of quite close contact between an actively infected patient and a susceptible person. For this reason, measles is both an infectious and a contagious disease, whereas malaria, which is transmitted by insects, and sometimes over a considerable distance, is an infectious but certainly not a contagious disease.

Defined in this way, infectious disease is the outward and

visible sign of the presence in our tissues of an alien species of life, which was not present before the illness began, which generally disappears when it is over, and which can be transmitted to other human beings if circumstances permit.

The alien forms of life which are responsible are of many different shapes and sizes, but all of them are what biologists know as parasites. That is to say, they are species which have forfeited their freedom for whatever advantages may accrue from their ability to survive and multiply in the tissues of another species. Since Man is not alone in possessing such parasites, it might be assumed that the parasites which afflict him now were evolved a very long time ago and, together with their diseases, have accompanied Man in the long process of evolution from more primitive forms of life. There are, however, formidable objections to so simple an explanation.

In discussing the probable origins of human infectious disease we are therefore faced with two complementary problems. The first is the origin of the parasites themselves without which there would be no infections, and the second the processes by which they became capable of producing disease. Neither admits of a ready solution, but discussion will be greatly facilitated if the reader possesses some preliminary knowledge of the habits of the parasites we know nowadays and the behaviour of the diseases they produce in the community. Essential preliminaries of this nature form the subject of this chapter.

The great majority of the living things in the world to-day are what are known as free-living species: that is to say, they can travel or at least choose their place of residence, obtaining the nourishment they require for growth and reproduction from inert compounds which are available to

them in Nature. Plants, for instance, grow wherever a suitable terrain is available and obtain their food from the carbon dioxide in the atmosphere and from simple salts absorbed from the soil. Most of the invertebrates and all the vertebrates derive theirs from more complicated materials such as cellulose, the fruits of various forms of vegetation or the protein in the bodies of once living creatures. An independent source of food supply of this nature allows them a considerable degree of movement as free agents. But the parasites have forfeited this freedom for the comparative safety of life in or on the tissues of another and usually much larger living thing, generally referred to as the host. Although the latter provides the parasite with food from its own tissues, and a certain amount of protection against many of the hazards to which free-living species are subject, the parasite has no control over its movements and is necessarily taken by the host on its wanderings. Indeed, its very life may be so dependent on that of its host that it too dies when the host dies.

It is, however, important to realize that although parasites may produce disease, this is not inevitable. Indeed, some parasites are actually beneficial to their hosts. Parasitism may, in fact, take three forms.[1]

In symbiosis (literally, living together) host and parasite operate to their mutual advantage. A good example of this is the association between white ants and the flagellated organisms which live in their intestinal canal. These aid their host by digesting the cellulose of the wood which forms its diet, while the host provides food for the organisms from its own tissues. Both symbiont and host are, therefore, necessary for the survival of the other.

Commensalism (implying eating at the same table) is also

a form of parasitism in which the parasite is associated with another form of life, but in this case neither would come to very much harm if the other left. The association of the hermit crab and the sea anemone is an example of commensalism. The former adopts the empty shell of a mollusc such as a whelk and carries it about with it in its wanderings. This gives it protection. But the outer surface of the shell frequently becomes the point of attachment of a sea anemone. This gives it a further degree of protection because fish object to sea anemones and give it, and the hermit crab beneath it, a wide berth. The sea anemone too benefits by this process because the mobility it enjoys in virtue of its attachment to the shell propelled by the hermit crab gives it access to supplies of food it would otherwise not have reached. But although both crab and sea anemone benefit by this arrangement, each can exist quite successfully in the absence of the other.

In the third form of parasitism, which may be called pathogenesis, or ability to produce disease, the parasite is generally only present in the tissues for a comparatively short time where it remains either localized somewhere to produce inflammation, necrosis of cells, haemorrhage, etc., or may become generalized by invasion of the blood vessels. But whether it remains localized or invades extensively, fever, rashes and other signs of its presence will occur, while there is always danger that the host may die as a result.

It is necessary to add that the term parasite has come to possess several different meanings and connotations. Some authors use it to embrace only parasites which are pathogenic. Medical men, on the other hand, generally limit it to include only the larger parasites such as tapeworms and roundworms. But a term is necessary which is sufficiently

general to include parasites of all sizes, whether they are symbionts, commensals or pathogens. Since "parasite" does provide this, and no other alternative is available, we shall use it in this all-embracing sense.

To describe all the parasites which may be found from time to time in human beings would be both wearying for the reader and extravagant of space. But they vary enormously in size, in shape, and in the manner in which they produce their offspring. The largest is the hydatid cyst, occasionally seen in Australia, which may be big enough to contain more than a gallon of fluid. The tapeworms are, by comparison, much smaller, but even so, their long thin ribbons may reach a length of several metres. The roundworms are about the size of an earthworm but the hookworms are only just visible to the naked eye.

The remaining species require the microscope or even the electron microscope to render them visible. Some of the largest are the microfilaria of elephantiasis and the protozoa of amoebic dysentery and malaria. Then come the trypanosomes of sleeping sickness and the spirochaetes of syphilis, yaws and relapsing fever, from 1/50 to 1/100 mm. in length and which are actively motile in the blood or tissue fluids. The fungi which cause ringworm and other forms of skin infection are quite incapable of movement but grow in the form of long, tangled, branching filaments. The bacteria consist of short cylinders or spheres. The largest, the bacillus which causes anthrax, is about 1/125 mm. long and the smallest are some of the cocci or spheres, *Veillonella*, for instance, being only about 1/2,000 mm. in diameter. Many organisms such as those of tuberculosis, typhoid, cholera, diphtheria, whooping cough and scarlet fever are intermediate in size between these two extremes. The viruses

and rickettsiae are the smallest forms of life we know, so that only the larger ones can be seen under the ordinary microscope. They are, for the most part, simple spheres, cubes or ovals. The largest of them, the virus of psittacosis, is about the same size as the smallest of the cocci, i.e. 1/2,000 mm., but those of typhus fever, smallpox, influenza, mumps and many others are all, in varying degrees, smaller until those of poliomyelitis and encephalitis are reached whose diameter is only about 1/100,000 mm.[2]

At the time of birth, the child is usually devoid of all parasites, but in the course of a few hours it acquires an abundant flora of commensals. They are probably derived from the mother or other human beings in its neighbourhood. The skin, for instance, is parasitized by staphylococci, the air passages by various forms of streptococci, and the gut by *Bact. coli*. Once settled, these organisms, together with many other species too numerous to mention, can maintain themselves throughout the lifetime of the new host. And only in rather exceptional circumstances do they ever do him any form of injury.

Pathogenic parasites do not behave in so kindly a fashion. As a general rule, they do not appear until an infection is active or impending. Their presence in the tissues is usually announced by the production of certain very definite and invariably unpleasant symptoms. And, if the patient recovers, the parasites generally disappear very soon afterwards.[3]

The immediate source from which pathogenic parasites may come is therefore a matter of some considerable importance, not only because it aids us in the practical business of preventing their harming us, but because of its bearings on the problem of their ultimate origin. To some extent, this is simplified for us by the marked degree of

specificity exhibited by parasites in their choice of a host. That is to say, the parasites which are able to survive and multiply in the tissues of one species of host are either unable to parasitize other species or will only do so with difficulty. In consequence, the great majority of human parasites are exclusively human possessions, and if we acquire one, our enquiries as to its source need only take human beings within our purview. This particularly applies to those causing colds, influenza, mumps, chicken pox, small-pox, whooping cough, diphtheria, pneumonia, syphilis, gonorrhoea, meningitis and measles.

Nevertheless, some pathogenic parasites do quite regularly come to us from animals. Such parasites are fundamentally animal parasites, and any extension of their activities to human beings must be looked upon as accidental and not necessary for their survival. One of the most important is the bacillus which causes plague. Although this disease has caused the death of millions of human beings, it is primarily a disease of rats, maintained and nurtured in rats, producing a severe and frequently fatal disease in them. It is only when Man is in the close proximity of infected animals that he can acquire the disease. In the same way, anthrax is fundamentally a disease of sheep, rabies of dogs, leptospirosis of rats and psittacosis of parrots, while the cow provides bovine tuberculosis, undulant fever and, sometimes, the salmonella of food infection.

A second group of parasites also comes from animals, but unlike those mentioned above, these find Man as important for their survival as is the animal. The two tapeworms, *Taenia saginata* and *T. solium*, for instance, are fundamentally human parasites in that the tapeworm stage of development is passed in the intestinal canal of Man, but the intermediate

stages (*cysticercus* or bladderworm) undergo development in the muscles of cattle and pigs respectively. Consumption of uncooked or only partially cooked meat containing these intermediate forms is the method by which these tapeworms are acquired. *Echinococcus granulosus* reverses this process. It is a tapeworm of the dog, but its intermediate host is Man, in whom it produces large bodies filled with fluid, known as hydatid cysts.

The parasites which produce schistosomiasis or bilharzial infection behave in somewhat similar fashion. The adult stage, or fluke, inhabits human beings and produces eggs which ultimately reach ponds and lakes inhabited by certain species of snail. Development of the eggs occurs in the snail with the production of free swimming larval forms or *cercariae*. These can then enter human beings by boring through the skin or by way of the stomach, thus completing the cycle.

Lastly, some species of parasite occasionally found in Man are not really parasites at all. *Proteus vulgaris*, *Pseudomonas pyocyanea* and several species of *Clostridia* are free-living bacilli which survive and multiply readily and easily in sewage, dead and rotting vegetation, or in the putrefying bodies of animals. The larval forms of a roundworm, *Strongyloides*, also undergo a developmental cycle in warm moist earth. None of these species really requires human beings at all. But all of them can, if occasion offers, parasitize human tissues and may even produce severe symptoms and death.

In view of the fact that parasites are generally able to multiply in the tissues of only one, or more rarely two, species of host, it follows that they must possess ways and means of travelling from host to host, and of maintaining

themselves in the tissues of these hosts for long periods of time. Unless they can do both of these things they are necessarily doomed. They undoubtedly vary greatly in their ability to do so. But if we confine ourselves to those parasites which are found as commensals or pathogens only in human beings, we may simplify discussion very considerably.

Although such parasites are able to multiply in many parts of the body, they can leave the body of their host only by certain definite and circumscribed routes, such as the mouth and nose, the faeces and urine, from suppurating wounds, or by being abstracted by insects when taking blood.

Organisms in the respiratory tract, for instance, may be projected into the atmosphere in the act of sneezing, coughing, talking, etc., or they may pollute the bedding, clothing or the skin of the donor and thus may obtain access to the respiratory tract of another person. Some of them may also be able to reach open wounds or the placental site after childbirth, in this way precipitating either pyogenic infection of the wound or puerperal sepsis. Those infecting the intestinal tract are present in large numbers in the faeces and may reach a water or milk supply. They may also pollute the fingers of the patient himself and in this way reach food consumed by other people. The organisms present in infected wounds or sinuses can be transported to other wounds by air currents or the fingers of nurses and surgeons. The venereal infections are almost always transmitted by the close and intimate contact of the sexual act.

A very large and important group of parasites are transported by insects. Some, such as the bacilli of dysentery, may be carried on the bodies of flies from the faeces of the patient to the food of other people. But others, such as the

protozoa of malaria, the rickettsiae of typhus and the virus of yellow fever, are abstracted from the peripheral blood of human beings. Having reached the digestive tract of an insect in this way, they either undergo a cycle of development in the cells of the alimentary tract (as occurs with the filaria of elephantiasis or the protozoa of malaria) or they travel to other parts of the body cavity where they, too, multiply. But whatever their behaviour, living infective parasites in large numbers eventually reach either the salivary glands or the faeces. In both of these situations, they are well placed to enter the tissues of a susceptible host, if the insect succeeds in finding one.

However they leave the body of the donor, and by whatever route they travel to new hosts, there is no doubt that the process is extremely wasteful. The very great majority of the parasites leaving an infected host quickly perish because the moment they reach the outside world they are subject to all manner of harmful agencies. Bright sunlight, excessive heat, great cold, certain degrees of humidity, and similar physical agencies are all inimical to some species of parasites. For this reason alone, it is obvious that a new host should be as close as possible to the donor. The fact that the surviving organisms may be quickly dissipated by air currents or, if they find their way into a water supply, may quickly be lost by dilution, renders close proximity even more desirable.

It is therefore unusual for the airborne respiratory infections to travel much further than the room or house in which the patient is living. And during the 1889–90 pandemic of influenza, when there were enormous numbers of infected individuals in all the adjacent countries, fishermen on the Dogger Bank and isolated lighthouse-keepers escaped

infection so long as they remained away from their bases. Indeed, the only infection capable of travelling any distance by air currents is smallpox. In severe cases of this disease, the eruption may release into the atmosphere large amounts of dried pustular material heavily charged with virus. Provided there is a sufficient number of patients in this condition, the air on the leeward side may become dangerous. When, therefore, the smallpox cases of London were nursed in hulks moored in the Long Reach of the Thames, many secondary infections developed amongst the unfortunate inhabitants of Purfleet, about half a mile downwind.

Parasites which reach a water supply do, undoubtedly, have a much wider range of activity, although the prospective victims are necessarily limited to those who drink the water without filtration or boiling, and who are on the downstream side. Moreover, streams and lakes have enormous powers of self-purification. But in spite of these hindrances, many typhoid, cholera and dysentery epidemics have occurred as a result of pollution of a water supply several miles away from the consumers. The same parasites may sometimes reach bulk milk. Here their opportunities are even greater because milk may be transported long distances and most of these parasites can grow in it provided the temperature is high enough and no attempt is made to inhibit them by pasteurization.

Those parasites transmitted by insects may appear to possess a wider range of activity than most. But the radius of action of the insect may be very limited, and it may be capable of transmitting the parasite for only a very short period of the year. Nevertheless, despite these limitations, insect-borne diseases have been the cause of some of the worst plagues from which Man has had to suffer.

Thus, even a heavily infected human being cannot disseminate his parasites over a very wide area. Infection in distant countries can only occur if the patient or his belongings contaminated by his parasites are transported thither. Infectious disease can, in short, travel, only as rapidly as human beings themselves.

When a parasite has found a new host, its struggles for survival are by no means over. If it is highly pathogenic it may produce a serious illness with large numbers of parasites in the body of its victim. They may reach the outside world to travel to other potential victims. But this state of affairs may persist for only a few days, at the end of which the patient has either recovered or died. In either event, the parasite is doomed because, in the process of recovery, the host generally kills his parasites, and even if he dies, most of the more delicate parasites die as well. In consequence, paradoxical as it may sound, the more violent its onslaught, the less chance there is of the eventual survival of the parasite.

Conversely, the gentler the behaviour of the parasite, the longer is it likely to survive in its new host, and the greater are its chances of finding still more hosts to parasitize. The gentlest parasites of all are the commensals. They do the host no harm whatever, and in all probability the host takes no steps to rid himself of them. It is probably for this reason that, to name only one species, the *Bact. coli* acquired by the baby soon after birth remains as a commensal in the intestine for the remainder of the life of its host. The opportunities of the progeny of the original organisms which colonized the child's gut to reach and colonize other human beings, must therefore be infinitely greater than those before a more violent parasite, such as that which causes

influenza, for in this disease the active life of the parasite in the tissues seldom exceeds one week.

Although in the great majority of patients, the organism disappears at the end of the acute phase of the infection, it may remain alive in a small proportion of the survivors. Having begun as a pathogen, it thereafter behaves as a commensal, doing its host no particular harm, but, unlike other commensals, it remains sufficiently pathogenic and virulent to produce illness and death if it is transmitted to susceptible individuals. The proportion of patients who become such carriers, as they are called, varies very considerably with different varieties of parasite. Thus, following diphtheria 5 per cent of the patients still have the organisms in the throat as long as seventy days after the illness and about 3 per cent of dysentery patients continue to excrete the organisms in the faeces indefinitely.[4] Some viruses behave in much the same fashion, remaining in the tissue in a latent or dormant phase. Nevertheless, many parasites cannot habituate themselves to this type of existence. In consequence, very few, if any, convalescents from cholera are carriers of the vibrio which causes that disease. And the same applies to patients recently recovered from virus infections such as measles, mumps, chicken pox and smallpox. But with all its limitations, the ability to remain viable and virulent in carriers must be of enormous benefit to those parasites which are able to do it.

A second method of securing survival is the production of a chronic infection which may last for many years, and with the parasites in such a situation that they can gain access to the outside world. One of the best examples of this is tuberculosis of the lungs. This may be a very long-continued infection with large numbers of tubercle bacilli

being coughed up by the patient all the time. It is not, therefore, very surprising that the incidence of the disease in families with one infected person in their midst is ten times greater than in uninfected families. From the point of view of the parasite, nothing could be better because it need not fear the swift and rapid extinction which a more virulent parasite would invite. Many other parasites may produce illnesses of an equally chronic nature ; we need only mention leprosy, yaws, syphilis, gonorrhoea and hookworm disease.

In the above instances, the parasite was attempting to survive, with varying degrees of success, in the tissues of its natural host. Attempts to survive outside the body are necessarily much less successful, because of the vulnerability of most parasites to the conditions they encounter there. But a few species can form spores, extremely resistant bodies, which may be able to survive for many years, to bring forth a new generation of adult forms if occasion offers. Others, particularly the viruses which are transmitted by insects, may remain dormant but alive for long periods in their insect vector and may even survive the winter, to appear in the progeny hatched a year later.

Thus, it is obvious that the chances of survival of the parasite are better if it goes no further than commensalism, in which both host and parasite agree to live and let live. Once it assumes a pathogenic role, particularly if it becomes highly virulent, its chances of survival are much more slender. And while some parasites have taken steps to overcome this disability, these may not be adequate. All in all, therefore, pathogenesis may be a characteristic that parasites would, if they possessed any choice in the matter, willingly lose.

Although pathogenic parasites can keep themselves alive

in the community by various devices, it is important that we should realize that some are more successful than others. For this reason, the behaviour of parasites in a human population does not invariably follow a set pattern. This is admirably demonstrated by the differences between cholera and typhoid. Typhoid was always present in the cities of Europe all through the nineteenth century. At that time, it was usually transmitted from person to person by the agency of water. Cholera is also transmitted by water and for this reason one might have expected that this disease would have behaved in the same way. But it only appeared at intervals, and although it produced quite severe epidemics, it only persisted for a few months at the time of each outbreak and then disappeared entirely.

If the particular habits and characteristics of the parasite play a part in determining the pattern of infection, the host himself is by no means a passive agent. He too has something to say. In all epidemics of any degree of severity, for instance, some persons escape infection despite every opportunity for acquiring it. No particular reason can be given for this, but it may be due in part to the possibility that some races of men are more resistant to certain parasites than are others. Jews, for instance, are generally considered to be less susceptible to tuberculosis than are Gentiles. To some extent, this may be a genetical peculiarity, for it has been found possible by selective breeding to produce races of mice, which are more, and other races, which are less, susceptible to certain organisms or viruses.

Relative insusceptibility may also be due, in part, to long-continued contact of the race with a particular parasite. It is, for instance, possible that white men, by reason of their long battle with the tubercle bacillus, have gradually,

in the course of the years, lost the more susceptible genetical lines to the disease and we, the survivors, are the more resistant. The North American Indians and the Esquimaux, whose contact with this organism is of much more recent date, have not yet had time to achieve this relative insusceptibility and, in consequence, tuberculosis is to them a much more serious and lethal disease. The same probably applies to the Kaffirs and other African tribes, and when large numbers of them were brought to France during the 1914–18 War, an alarmingly high proportion contracted the disease. There was, for instance, more tuberculosis amongst 11,000 Cape Boys and Kaffirs than all the 1,500,000 British troops who went to France.

Immunity may also be acquired in the course of one's lifetime. Following recovery from an infection, the individual is generally immune to reinfection by that particular parasite because, in the process of recovery, he manufactures antibodies which can protect him in the future. But the length of time that this immunity persists is very variable. With the virus of smallpox or that of yellow fever, or the microbes of typhoid or diphtheria, one attack generally produces immunity that lasts as long as the individual lives. But with the virus of herpes or the common cold, it may not last for very long.

It is, however, not necessary to go through all the miseries of an acute infection to obtain this immunity. It can be achieved by what is known as subclinical infection. This, as its name implies, means that the individual has had either a very indefinite and atypical illness, or possibly no illness at all, but in spite of this the organisms have been present in his tissues and have produced sufficient stimulation of his antibody apparatus to induce it to secrete the necessary antibodies. This tends to occur during childhood, and it is

for this reason that many adults are immune to such relatively common infections as diphtheria and scarlet fever, without having actually suffered from either of these diseases in a clinically recognizable form.

It is, however, very important that we should realize that immunity produced as a result of clinically recognizable infection or subclinical infection is extremely specific. A previous infection by the virus of measles will generally protect us against another attack of measles, but it has no effect on our susceptibility to any other parasitic infection. But one attack of pneumonia, for instance, may have a very limited protective value, because there are at least eighty different types of the pneumococcus, each one producing immunity which is only specific against reinfection by pneumococci of its own type. It is therefore conceivable that one might, although such an event is unlikely, have pneumonia eighty different times in the course of one's lifetime.

Many other factors may also play a part in modifying the susceptibility of the individual. There is, for instance, evidence that some parasites may be present in the tissues for long periods and either remain latent or, even if multiplying, doing no particular harm. A change in the local conditions may, however, alter this rather precarious balance. Thus, the *Bact. coli* which are normally present in the intestinal tract are for all practical purposes harmless commensals. But only so long as the wall of the intestine is intact. If it be injured by wounding, the organisms can then obtain access to the peritoneal cavity, where they may produce a very severe peritonitis which may imperil the life of the host. A somewhat similar process may occur in extreme degrees of vitamin deficiency, particularly of vitamin A. This produces massive destruction of the outer layers of the

mucous membranes, allowing secondary infection by previously harmless commensals. A virus infection may have the same effect. In influenza and the common cold, there is a somewhat similar destruction of the cells in the mucous membranes, allowing secondary invading organisms access to the tissues below.

More remote stimuli may also determine the occurrence of infection. A virus, that of herpes, is known to inhabit the tissues of many of us without showing evidence of its presence by producing the characteristic lesions. But if the local conditions are modified in some way, the virus may become active, and produce the sores announcing its presence.

Much less is known about the effects, if any, that starvation or semi-starvation, excessive fatigue, addiction to alcohol, and other factors may have on the immunity of the individual. It is possible that an inadequate diet may render the individual abnormally susceptible to tuberculosis. Beyond this, it would be unsafe to go.

When, therefore, we come to consider the reaction of the community, rather than the individual, to its parasites, it is obvious that a great many different factors must play an important part in determining how much, and how severe, their parasitic infections will be. The particular variety of parasite involved, its ability to produce infection at all, and its virulence or ability to kill, are equalled in importance by such factors as its ultimate source, its ability to survive the hazards of the outside world on its way from donor to recipient, and the frequency with which it produces carriers or chronic infections. The community itself may also play an important part. Whether or not its members have had previous experience of the parasite will, to a large extent, determine their ability to resist its onslaught. The amount

of food they consume and its vitamin content may have effects on their susceptibility. Their standards of hygiene will play an important part in determining how much intestinal infection they will suffer. Even their personal cleanliness matters because the louse which conveys typhus generally appears if ablution is neglected. The construction of their houses can determine how close to rats they come and, in consequence, their chances of acquiring plague. A liking for uncooked food may determine the incidence of tapeworms or, in countries with rudimentary ideas of hygiene, of typhoid or dysentery. Even so apparently unrelated a matter as the wearing of shoes may make all the difference in parts of the world which are infested with hookworm. And lastly, geographical location may have a very great deal to do with the occurrence of many infections, particularly those transmitted by insects.

Other things being equal, one of the most important factors is the closeness of contact between the individual units of the community. There is now very little doubt that when a member of a family acquires a new parasite, particularly if it be one which makes its home in the respiratory tract, it is quickly transmitted to other members of the family, to produce either cases or carriers. But transfer of infection from family to family depends partly on the distance between the families, and partly on the habits of the parasite involved. When the contact is close, as in a large city, the transfer of infection from family to family undoubtedly occurs without very much difficulty.

In London, for instance, a population of about 10 million persons is concentrated in a comparatively small area, and with ample opportunity for the spread of infection from family to family. There is also every year, an appreciable

influx of susceptibles, such as new-born children or immigrants without immunity because they have come from uninfected localities. Unless disturbing factors such as artificial immunization are introduced, many forms of parasitic infection need never die out in such a community.

Small, isolated communities, on the other hand, behave somewhat differently. There is a marked tendency for them to escape many of the infections which are common in more accessible places. Many years ago, Sir John Simon quoted the example of the Scilly Isles which in the decade 1851 to 1861 did not have a single death from measles, scarlet fever or diphtheria. During the same period, all of the other 626 registration districts of England had deaths from these diseases, the mortality rate for the whole country being 409 per 100,000 from scarlet fever, 103 from measles, and 280 from diphtheria.

This freedom from parasitic infection is even more marked in the case of completely isolated areas. Much is now known about the behaviour of Esquimaux and of Indian tribes in the far north of Canada, of parties of Arctic and Antarctic explorers, and of isolated islands such as Spitzbergen, Tristan da Cunha and those of Polynesia, all of which, cut off from the rest of the world by vast distances, may be isolated for long periods of time. On the whole, they behave with striking uniformity, in that so long as they remain isolated (and so long as they do not go into isolation with a chronic infection in their midst) they remain free of the common infectious diseases.

The island of Tristan da Cunha, remote in the South Atlantic, is visited only very infrequently. Its population was about 180 just before the recent war. There has been a considerable amount of intermarriage. The diet consists, for

the most part, of fish and potatoes, with a few other vegetables and a very little milk. It is, therefore, deficient in vitamins. The sanitation of the settlement is poor, and the drinking water is almost certainly contaminated by their excreta. The climate is cold, wet and stormy, with very little sunshine. But in spite of these shortcomings, the inhabitants are extremely healthy. Their only participation in the history of infectious disease has been two outbreaks of mumps in 1890 and 1910, and one of "angina" in 1920. Measles, scarlet fever, whooping cough, diphtheria and tuberculosis have not reached them. They are even free from colds, but only for so long as they remain isolated; the arrival of a boat, particularly if it has recently called at a port, is almost invariably followed by a severe outbreak of colds. But these soon die away and the island settles down again to a cold-free existence until the next boat arrives.[5]

The behaviour of the common cold in an isolated community was the subject of a special investigation by Drs. Paul and Freese, who spent eleven months in Spitzbergen.[6] This island, situated far to the north of Europe in the Arctic Ocean, possessed a population of 507 persons during the winter of 1930–1. They were mostly engaged in coal-mining and lived in very cramped quarters in Longyear City. There is no sun for four months of every winter and the average weekly temperature may become as low as −12° F. At that time, the island was completely isolated from Europe by the ice packs for seven months between October and May.

During the early part of October, when communication with Europe was still possible, there were numerous colds, but with the departure of the last boat in the week ending October 25, the number contracted by the inhabitants

slowly diminished week by week, until, during February, March and April and the early part of May, only one or two colds a week were observed. It is obvious, therefore, that the community had come to an understanding with the particular virus responsible for the common cold which was present amongst them at the beginning of winter. Either it had died out altogether or, if it persisted, the community had developed sufficient immunity to prevent actual infection developing.

When, however, the first of the next summer's boats arrived after the winter on May 23, 1931, within forty-eight hours large numbers of colds had been contracted by the inhabitants, due undoubtedly to virus present amongst the crew or passengers of the incoming vessel.

Thus, small isolated communities do escape a great deal of the parasitic infection which constantly plagues large populations. But there is one disadvantage in this freedom. The community acquires very little immunity. In consequence, its members quickly become infected if, by chance, pathogenic organisms reach them, or if they emigrate to a city, military camp or other large centre of population, with its permanent reservoir of endemic infections.[7]

It is thus obvious that many factors play an important part in determining the extent and severity of parasitic infection in a community. But three factors stand out : the ability or otherwise of the parasite to maintain itself in the community; the amount of previous infection the community may have had by that particular parasite; the size, the degree of dispersion and the isolation of the community. The importance of these factors in the history of parasitism and infectious disease in the human race will emerge in the next chapter.

CHAPTER TWO

MAN AND HIS PARASITES

Oh! let us never, never doubt
What nobody is sure about!

HILAIRE BELLOC.

IT IS PROBABLE that the first forms of life to be evolved on this planet were floating masses of protoplasm which in time acquired a cell wall and became unicellular organisms not very unlike some of the parasites we know to-day. Walcott has, for instance, actually detected cocci closely resembling the nitrifying bacteria of the soil of the present day in the Algonkian limestones of Montana. If, as seems probable, these are pre-Cambrian, this gives them an age of 520,000,000 years.[1] What particular combination of circumstances produced from the inert inorganic world the highly complicated materials of which even the simplest of these micro-organisms is constructed is well beyond our ken. But develop they did, and continue to do so.

These first species were undoubtedly living free in water, and probably obtained their nitrogen from an ammonium compound. Some of them may well have remained unaltered to the present day; organisms of this type of economy still exist. But fishes, amphibians, mammals and lastly Man himself were, in the course of the ages, evolved from living matter of this description.

It is quite probable that comparatively soon in the evolutionary process, some of these primitive forms exchanged the freedom of an independent existence for the

comparative security of the tissues of a larger form of life, which provided them with both shelter and nourishment. There is no reason for supposing that these early parasites were necessarily dangerous to their hosts. They were probably either symbionts or commensals. But there is adequate evidence that ability to produce disease, that is the assumption of harmful pathogenic attributes, occurred a very long time ago. Osteomyelitis of the spine, probably due to staphylococci, has, for instance, been found in a fossil reptile, *Dimetrodon*, in Permian strata, which gives it a date of 195,000,000 to 220,000,000 years ago. A dental abscess has been detected in a *Dinosaur* of the Cretacious (75,000,000 to 140,000,000 years ago), and an alveolar abscess in a *Titanothere* or rhinoceros of the Lower Eocene (45,000,000 to 75,000,000 years ago). Coming to almost recent times, actinomycosis has been found in the remains of a three-toed horse of the Miocene who roamed the earth only 15,000,000 to 35,000,000 years ago.[2]

In view of this, it might be thought that Man has brought his parasites with him all through the years of his development. This may well be true of some of them. The less harmful commensals such as the staphylococci of the skin, the streptococci of the throat and the coliform organisms of the bowel are not only parasites of all human beings but of many animals as well. To a bacteriologist, it is difficult to imagine a human being living without them, so that they may well have come with Man in the course of his evolution.

But it is very difficult to visualize the pathogens coming to us in this way. There is, for instance, such a multiplicity of genera and species which can produce infection and illness in Man. Even if we omit all the viruses, rickettsiae, protozoa and the larger parasites such as helminths and

tapeworms, there are well over twenty genera of bacteria containing one or more species which can live in human tissues. One of them, the *Salmonella*, possesses over a hundred species, while the pneumococcus is divisible into eighty different types and the streptococcus into forty. Each of these types is so chemically distinct from all the other types that they could be considered as distinct species.

For a very long time, there cannot have been very many human beings. If, therefore, all the many different species and types of parasite we know to-day had come to us from a simian ancestor, this would have necessitated the simultaneous parasitization of practically every human being then in existence, by a number of quite dangerous and virulent parasites. If this had occurred, it is difficult to imagine how Man succeeded in surviving at all.

It is, moreover, a reasonable assumption that if most of the known parasites had been active amongst our simian ancestors and the early hominids, some of the more hardy varieties would have survived in both *Homo sapiens* and parallel lines of development such as the *Primates*. But the higher apes are not, so far as we know, infected in their natural habitat by organisms responsible for human infection, even though they may be susceptible when infected artificially or are in close contact with Man.

But perhaps the most cogent argument against a simian origin for most of our parasites is the probable behaviour of early Man himself. For it was pointed out in Chapter I that the ability of parasites to establish themselves in any community depends to a very large extent on its degree of dispersion. In a crowded city with a large population they would have little difficulty but in a series of small groups, spread out over a wide extent of country, it would be quite

otherwise. Study of the early stages in human development shows that this is the type of community which the parasites would have to face.

It is probable that the first creatures to bear any resemblance to human beings first walked the earth about half a million years ago. They differed from the men of the present day in a number of important respects, such as in the volume of the brain (and therefore in intelligence), the shape of the forehead, the size of the jaw, and the manner in which they walked. It is almost certain that some of the first races died out at an early stage of development. But in spite of false starts, men eventually appeared whose cranial capacity, shape of face and jaw and whose gait were sufficiently close to that of the men of the present day, to warrant the term *Homo sapiens*. We are their lineal descendants.[3]

It is probable that this development took place more or less simultaneously in several places. We do not know exactly where: it was not in America, Australia, New Zealand or the Pacific Islands, but somewhere in Europe, Asia or Africa.

These early men were very few and far between and probably felt very lonely. But they had at least acquired the power of speech. They could make tools out of stone or bone or wood, with which to hunt game or obtain roots from the earth. They had also learnt how to make fire, to use it and to control it. They lived in tents, or in underground houses roofed with skins or turf, or may have contented themselves with nothing better than a few branches set up as a windbreak. If they possessed clothing at all, it was made from skins sewn together with bone needles. They had progressed a very long way from the animals on the evolutionary road.

They were what archaeologists call food gatherers, who made no attempts to obtain a harvest by planting or sowing seeds, or to improve their food supply by the breeding and domestication of animals. An important aspect of an economy of this nature is that it will not allow of the growth of any great density of population. It has been calculated that on the prairies of North America, where the Red Indians until comparatively recently obtained their food in this way, mostly by hunting buffalo, an area of at least nine square miles was required to feed one individual. In Australia, where the supply of food was much less plentiful, 33 square miles were necessary.

Thus, it is probable that they were forced to live in relatively small groups of families, which were completely self-sufficient and separated from other similar groups by quite long distances. There may have been some communication between these groups, because there are indications that cultures and techniques developed in one place eventually appeared in others. But it cannot have been very extensive.

There seems little doubt that from the time human beings first became differentiated about 500,000 years ago, until villages and towns first made their appearance between 18,000 and 6,000 B.C., their mode of life was of this order. This period which comprises about 98 per cent of the time Man has taken to develop, is known as the Palæolithic period.

During most of this time, Man was very near to the animal world and its parasites. They could therefore transfer their activities to him. But this would necessarily depend on their distribution in the local animals, so that some family groups might acquire some types of parasite and other groups, other types. Nevertheless, the commonest would

probably be tapeworms, roundworms and hydatid cysts, as Palæolithic Man was probably much given to the consumption of raw or only partially cooked meat.

If the man of this period injured himself, he probably ran much the same risks of wound infection as nowadays. The staphylococci would almost certainly play a part in this. As already mentioned Man may well have brought them with him. But he was probably spared the far more serious infections caused by *Strep. pyogenes*; this organism is unusual even nowadays and the isolation of Palæolithic Man probably defeated it. His own *Bact. coli* would probably give him peritonitis if the wound penetrated his intestines, while the animals to which he was so close could quite easily provide the spores to give him tetanus and gas gangrene.

But when we come to consider the great majority of the parasites which are pathogenic for Man, those of measles, diphtheria, typhoid or even so mundane a disease as the common cold, the fact that Man and Man alone is their natural host must have been a serious hindrance to them. For in the extreme isolation of his family groups Palæolithic Man was, epidemiologically, in the same category as the inhabitants of Tristan da Cunha or Spitzbergen of the present day rather than those of New York or London. If therefore a group of Palæolithic men acquired a parasite of the high degree of specificity characteristic of those of the diseases mentioned above, it would have had a formidable task before it. The group would almost certainly have never previously encountered it. All or nearly all, the group would therefore become infected, because they would possess no immunity. For the same reason, they would be infected very badly, and a high proportion would probably die. Those

infected would make matters worse as primitive people afflicted with fever usually do, by indulging in total immersion in cold water or by lying naked on the ground, in order to cool themselves.[4] If these measures did not make them much worse, the fact that they were food gatherers meant that they were probably without reserves, and, the whole group being infected at once, those who were still alive would be starving in a day or so. This alone would suffice to wipe out those who had managed to survive the onslaught of the parasite.[5]

The end result of all this would be the extinction or near extinction of the whole group, in utter isolation. Despite the fact that it was apparently fulfilling its destiny in no uncertain fashion, the parasite would soon be unable to find new hosts. It would therefore die out in a very short space of time. So far as the parasite is concerned, it is difficult to imagine anything more unprofitable. It would have secured its own extinction by the success of its onslaught.

If the parasite behaved like the tubercle bacillus or the spirochaete of syphilis, it would undoubtedly fare very much better. But here again, it would have Man's perversity to contend with. For it would survive only if it did not disable its victims too seriously. A long lingering illness, which renders the patients incapable of fending for themselves, is not a very welcome event in a tribe which is living a hand to mouth existence as food gatherers. Passengers cannot be permitted under such circumstances. As Professor Lyle Cummins has pointed out[6] such invalids amongst primitive people are not accorded the care a more civilized community would give them. If they are not killed outright, they are generally neglected or left somewhere to die. Reprehensible

as this behaviour may be, it does allow of survival of the group and although they would not have known it, may even have saved them from further cases of the disease.

Even if it did not kill the major part of the group, or produce chronic invaliding infections, the parasite's future would still be precarious. For just as the inhabitants of Tristan da Cunha or Spitzbergen do at the present time with the virus of the common cold, the group would probably come to some sort of understanding with the parasite. Some of its members might act as carriers. But quite a proportion of carriers tend to lose their organisms eventually, and in any case, such a mode of existence is not very profitable for the parasite itself. Unless, therefore, new susceptibles were obtained from a neighbouring group within a reasonable time, even the more gentle parasites could die out.

For these reasons, it is improbable that many of the pathogenic parasites which we know to-day were very active amongst Palæolithic men. They were operating in a partial vacuum and what victories they achieved were, for the most part, Pyrrhic victories.

Unfortunately, much of this is pure conjecture, because our only information about these people is derived from the few tools that they have left behind, the pictures they drew in the depths of the earth in France, and a few skeletal remains. Even the latter do not help us much because, with a few exceptions, most parasitic infections leave no trace in the bones. At all events, no very definite evidence of parasitic infection in Palæolithic remains has come down to us.

There is, however, other indirect evidence which suggests that they were free of most of the common infections. Three

major areas of the globe were colonized from the Old World during late Palæolithic times. If the colonists had come from heavily infected communities, one would expect that some of the hardier parasitic infections would have gone with them and survived in their descendants. But there is a great deal of evidence that they did not and that at the time of their discovery by European explorers, their descendants were free of these diseases.

America was undoubtedly colonized from about 12,000 B.C. onwards, by waves of immigrants who came from northern Asia by way of the Behring Straits. Tierra del Fuego at the southern end of the land mass was reached about 2,000 B.C.[7] The great majority of the resulting communities remained Palæolithic or early Neolithic in culture. And when, following its discovery by Columbus in 1493, the exploration of America by the white man was begun, none of the infectious diseases which had been rampant in the Old World for centuries was found amongst the natives. But these diseases developed soon afterwards and with the dire results to be expected in a hitherto uninfected population.[8]

It is, for instance, highly improbable that smallpox was present anywhere on the continent, but it certainly reached Haiti in 1507 being imported by Negro slaves from Africa and thence it travelled to the mainland in 1520. Before the end of the century, it had gone southwards as far as the Argentine.[9] New England was infected in 1633 and the St. Lawrence basin a year later.[10] Greenland had to wait until 1733 and California until the nineteenth century.[11] Measles probably came to Mexico as early as 1531[12] and to Brazil in 1560, but not until 1846 did it reach California and 1864, Greenland.[13] Scarlet fever did not appear until 1735.[14]

Leprosy, yaws and hookworm, all of which became widespread,[15] were probably introduced by Negro slaves from Africa.

There has, however, been a considerable amount of controversy in regard to the possible presence of tuberculosis before Columbus. Neither Moodie nor Hrdlicka, whose knowledge of palæopathology was unrivalled, was able to satisfy himself that signs of the disease were detectable in any of the many skeletal remains of undoubted pre-Columbian origin, they examined.[16, 17] Nevertheless, if it was brought by the white man, it certainly became relatively common amongst the North American Indians by the middle of the seventeenth century.[18] And their mode of life was admirably adapted to render it an extremely infectious and lethal disease.

On the other hand, syphilis is frequently considered to have been an American disease, introduced into Europe by the sailors of Columbus. This is a very debatable point, but as with tuberculosis there certainly seems to be very little evidence of its presence on the mainland of America.[19] Nor is there any reason to suppose that yellow fever, which eventually became so important an American disease, was present anywhere before 1647 when it was first observed in Barbadoes, and, only a year later, in Guadaloupe, Havana and Yucatan. It was not very long before it had spread to the mainland and as far north as Boston.[20]

Australia and Tasmania also played no part in the development of *Homo sapiens* but were colonized from southern Asia. Exactly how, and still less when, this occurred is not known, but it was probably by way of New Guinea and the Torres Straits. The economy of their descendants has remained Palæolithic, with Stone Age weapons, no

attempt at agriculture or the herding of animals, no villages, and with so widely dispersed a population that it has been estimated that only 200,000 can have lived there at one time.

Other than the early voyages of the Portuguese, Spanish and Dutch explorers, the first European contact with Australia was made by Cook on his first voyage and neither he nor Banks,[21] who was a singularly acute observer, could detect much illness amongst the natives. The common European infections were certainly absent. The early convict colonies were established in 1788 in Botany Bay, in Tasmania in 1803, and in New South Wales in 1835, and seem to have suffered much from dysentery and similar infections imported from their ships. There also seems to have been a small localized outbreak of smallpox in 1789.[22] But scarlet fever did not appear until 1847, and measles not until 1851. In Tasmania, measles first came in 1854, scarlet fever in 1843, diphtheria in 1859, whooping cough in 1842, and influenza in 1838. Pulmonary tuberculosis was well established by 1865.[23]

New Zealand and the islands of Polynesia were first populated at a very much later date than America or Australia. The colonists undoubtedly came by boat and many of them can tell us on which boat their forefathers came! Unfortunately, they do not know whence they came, but it is probable that they all came from the same region because from Hawaii in the north to New Zealand in the south, they all speak variants of the same language. It is also probable that two waves of settlers came, the first about A.D. 500 and the second about A.D. 1000.

Their economy was perhaps on a higher plane than that of the Australians. They had at least learned to cultivate the sweet potato and to breed hogs, chickens and even dogs

for food. Nevertheless, they still depended on stone for their tools and weapons, while the art of the potter had escaped them.[24]

According to Cook and Banks, the Polynesians of Tahiti were extremely healthy and even severe wounds did not suppurate. Venereal diseases seem to have appeared quite soon, being introduced by the crew of a French ship sometime between Cook's second and third voyages.[25] New Zealand, too, was free of most of the common infections, but following its first colonization in 1840 came influenza in 1844, whooping cough in 1847 and measles in 1854. Tuberculosis was completely absent amongst the Maoris at the time of their first contact with the white man, but by 1863 had become so common that scrofula was rampant everywhere and half the deaths of children under ten were due to tabes mesenterica.[26] Smallpox was first observed in Tahiti and Hawaii in 1853, in New Caledonia in 1859, and in the Marquesas in 1863. Measles came to Hawaii in 1848, Tahiti and the Marquesas in 1854 while Fiji had to wait until 1875, but when it came, it produced one of the most devastating outbreaks of the disease in all history.[27] Tuberculosis too was almost certainly absent and all authorities are agreed that it was the white man who brought it to Fiji, Tonga, Samoa, Tahiti, the Marquesas, Hawaii and New Caledonia.[28] Leprosy was also imported, but from China, and the first cases were seen in Hawaii in 1853, and in New Caledonia in 1865.[29]

Thus although the available information is scanty and incomplete, there seems little doubt that America, Australia and Polynesia remained free of most of the parasitic infections of the Old World until the time of their discovery by the white man. It is, however, possible that they had

their own parasites, which may have been unknown in the Old World. This would hardly be surprising in view of the fact that although most of the American continent was sparsely populated, civilizations flourished in the Inca, Aztec and Maya countries. Here there were undoubtedly sufficient concentrations of people to permit of the development and establishment of human parasites.

It is, for instance, very probable that the Incas of Peru were acquainted with some form of malaria because they evidently knew of the value of quinine for the treatment of fevers. It is also recorded that highland Indians quickly died if they were taken to the lowlands. If their presence there was required in any numbers, a system of relays was employed to ensure that none had to remain too long.[30] Malaria may also have been present in Mexico, because intermittent fevers seem to have been observed at the time of the conquest.[31] Calenturas and agues too seem to have been common in many parts of North America and particularly in the valley of the Mississippi when it was first visited by the white man.[32]

The Incas were also afflicted by verruga peruana and uta, both of which diseases still occur in Peru and Colombia. The first, also known as oroya fever, is an ulcerative infection due to a minute organism called *Bartonella*. Portrait vases of undoubted pre-Columbian date have been discovered showing the characteristic lesions, and about a quarter of Pizarro's army of 700 men are said to have died of it.[33] The second disease, uta, is also very distinctive, producing severe ulceration of the mouth and nose. It is due to an extremely small parasite, closely related to the *Leishmania*, which produces kala azar in Burma and the neighbouring countries. That it was present in America before the

conquest is proved by water jars of Peruvian pottery showing faces with the lesions in the region of the mouth.[34]

The natives of Brazil may have been afflicted by amoebic dysentery because they knew that ipecacuanha was of value for the treatment of certain forms of dysentery, and modern research has shown that emetine, its active principle, has a specific action on *Entamoeba histolytica*, the cause of the disease.

As already mentioned, the Aztecs may have had some form of malaria, but despite Dr. Carter's studies of their medical history, it is impossible to obtain much information about their illnesses other than a Nahuatl picture of the year 1454 showing the vomiting of what appear to be worms. Nevertheless, Prof. Zinsser considered, on what appears to be very flimsy evidence, that they may have had some form of typhus,[35] and they may have had mal de los pintos or pinta, a spirochaetal infection closely resembling yaws.[36]

Even less is known about the diseases of the Red Indian tribes. But the fact that their pharmacopoeia included chenopodium, suggests that they were afflicted by worms. Indeed, as so much of their diet consisted of meat, it would have been surprising had they remained free of them.[37]

There is, then, very considerable doubt whether the original inhabitants of America had taken with them any of the common diseases of the Old World, with the possible exception of malaria. Some of these diseases such as tuberculosis, ankylostomiasis and leprosy, are not likely to die out if once introduced into a primitive people. The inhabitants of Australia and Polynesia too, seem to have been free of all the common parasites of the Old World up to the time of the arrival of Europeans. In view of this, it is probable that the men inhabiting the eastern part of Asia, from which

one must presume most of these areas were colonized, were also free of these infections at that particular epoch in the history of Mankind.

Whether the inhabitants of Europe, Africa, and western Asia were equally free is, however, another question. Very little is known about the amount of contact there was between China, for instance, and Egypt. But so long as the Chinese and Egyptians were content to remain more or less isolated food gatherers, it is improbable that there was a great deal of contact. And for the same reason, it is improbable that parasites troubled either country very much.

But they did not remain untroubled. About the end of the last period of glaciation, when the ice sheet was slowly retreating and tundra and forests were growing up in its place, a change began to occur in human economy. Food gathering began to give place to food growing. Men had learned that if certain grains were planted in the spring, they would yield a crop by the end of summer, which, if they were lucky, might provide enough food to last them through to the next harvest. This step was probably accompanied by another which was equally important, the taming and domestication of animals. The invention of pottery, too, may date from this time.

An agricultural economy, whether depending on the cultivation of fields or the herding of domesticated animals, not only allowed the development of a considerably larger population in the same area than was possible in a food gathering economy, but permitted the foundation and settlement of more or less permanent villages. For a very long time, these were undoubtedly extremely few and far between, but eventually they became quite large, with extensive agricultural areas about them.

Exactly when Man left Palæolithic barbarism for the comparative security of the Neolithic village is a very controversial matter, but in Egypt and Mesopotamia, where it probably occurred first of all, between 18,000 and 6,000 B.C. has been suggested by different authorities.[38] But it almost certainly did not occur everywhere at once, and the full Neolithic culture may not have reached the Baltic until 2,500 B.C. Tacitus mentions that even as late as the first century A.D., the German tribes had not evolved the village, preferring to live in isolated houses on their homesteads. Nor must it be assumed that if the step had once been taken, it necessarily became permanent. In Palestine, for instance, communities which had developed villages and had lived in them for long periods, disappeared and were replaced by nomads living in tents.[39]

But once life in villages had been shown to be possible, it was not very long before cities made their appearance. These permit of an even more rapid increase in population, and also allow of quite a large proportion of the population becoming specialists for the manufacture of tools, the staffing of a civil service, or for the ministrations of religion. Cities are also easier to defend than scattered villages.

This urban revolution seems to have started in what has been called the Fertile Crescent. Its western horn consisted of the Nile valley, continuing by way of Palestine into Iraq, and then down the valleys of the Tigris and Euphrates to form its eastern horn. This area seems to have been particularly suited to this form of development because both the Nile and the rivers of Mesopotamia bring down large quantities of silt every year to renew the fertility of the fields in their vicinity. While this in itself was of great assistance in an age which knew little about manuring and

fallowing, the proximity of the rivers themselves enabled crops to be obtained by irrigation even in times of drought. About this time, copper tools and, later, iron began to replace those made of flint or horn, the potter's wheel was invented, and ox carts and pack animals replaced men's backs as beasts of burden.

All this Neolithic urban bustle was housed, in the case of Ur, inside an area of 220 acres, surrounded by a brick wall and fosse, looking out over gardens, fields and pastures, and canals full of fish and bearing boats bringing copper from Oman in the Persian Gulf, tin from Syria, Asia Minor or Drangiana in Iran, timber from Syria and the mountains to the north east, stone for querns and doorposts from Oman, and silver and lead from the Taurus mountains. Luxury goods, too, made their appearance, with lapis lazuli from Badakshan, mother of pearl from the Persian Gulf and shells from India.

As may be imagined, the date on which the first cities were founded is by no means certain, but this development probably took place some time between 5,000 and 4,000 B.C. Once it had been demonstrated that community life was possible, other towns and cities began to appear on the shores of the Mediterranean and of the Indian Ocean.

The herding together of large numbers of men in the cities and villages of the Fertile Crescent was probably the first occasion in the history of Mankind when parasites were enabled to produce infection in any quantity. No longer did they face extinction in the emptiness of the Palæolithic world. There were now men in plenty, some to kill, some to act as hosts for chronic infections and some in whom to persist as carriers.

It is hardly surprising, therefore, that what early records

we possess from this part of the world have much to say about parasitic infections. It is probable, for instance, that tuberculosis of the spine occurred in Egypt before 3,000 B.C., since remains showing Pott's disease have been discovered in pre-Dynastic burials. Sir Marc Armand Ruffer found a mummy with the same type of lesion dating from about 1,000 B.C. The same worker found evidence of pneumonia in a mummy of the XX Dynasty (1,250–1,000 B.C.) and the calcified eggs of *Schistosoma haematobium* in the kidneys of two mummies of the same date. Multiple kidney abscesses, spots on the skin resembling those of smallpox in a mummy dating from about 1,200 B.C., and one case of leprosy have also been recorded.[40] Infections in the mouth seem to have been rampant from very early times; pyorrhoea has been repeatedly detected, and tooth abscesses are by no means unusual. The Papyrus Ebers provides additional information for the period about 1,700 B.C., and amongst other pathological conditions refers to something closely resembling erysipelas and an infection of the eye not unlike trachoma.[41]

Although Greece is not actually in the Fertile Crescent, it is so close that it probably imported the diseases prevalent there. If, as seems probable, the Iliad was composed about the ninth century B.C., the fact that the whole theme hinges on a pestilence sent by Apollo to the Acheans besieging Troy shows that parasites were quite as active as in Egypt. But it is the fifth century which provides the most detailed information in the writings of Hippocrates and his school.[42] The most important for the present purpose are the forty-two case histories in Books I and III, but other references are also extremely valuable. Five of the patients undoubtedly had typhoid fever,[43] and two had meningitis or something very similar.[44] There is an infected foot[45] which from its

severity makes one suspect either a streptococcal infection or gas gangrene. There are also five cases of puerperal infection, two of them following miscarriages and the remainder after full term delivery.[46] Under Constitution 2 of Book III of the Epidemics, the frequent occurrence of erysipelas in connection with sore throat is mentioned. There is one case of osteomyelitis dying on the fourth day,[47] and one of dysentery dying on the seventh day.[48] Another case[49] in which there were infected glands in the neck with inability to swallow may have been diphtheria with paralysis of the soft palate.

Pulmonary consumption of a peculiarly severe and rapidly fatal variety seems to have been common. Tetanus and an epidemic resembling influenza are mentioned in Book VI. But perhaps the most interesting of all are epidemics of mumps[50] and infectious hepatitis or jaundice.[51] Tertian and quartian fevers, almost certainly malarial, are also referred to. Indeed Mr. Jones has suggested that because references by the early Greek writers such as Hesiod, to diseases resembling malaria are unusual, and that some of the most flourishing communities grew up in what eventually became extremely malarious areas, the disease was rare before 500 B.C. but that because of the increase of population, it became commoner, and from 400 B.C. has remained as an endemic disease, responsible in large part for the decline of Greek power and influence which set in about that time.[52]

In many respects, the Mosaic Law of the Israelites in Palestine also has a modern ring about it. The minute directions for the diagnosis of leprosy and the disposal of the patient indicate clearly that they had had long experience of the disease. The treatment of "issues" shows that they not only appreciated the dangers of this type of infection

but had a very clear idea of how it spread, and of the best methods for controlling it. We are not told whether "issues" implied gonorrhoea or purulent discharges from scrofula and similar types of infection, but they clearly indicate some form of bacterial infection.

Much less is known about the epidemiological history of the eastern horn of the Fertile Crescent, but the Hittite civilization seems to have come to an end following an outbreak of infectious disease identified as smallpox.[53] And, certainly, the layout of such cities as Ur or Kish suggests that with relatively large populations huddled together within the walls, a water supply from shallow wells or rivers, and a surrounding countryside seamed with canals for the nurture of mosquitoes, parasites would have been singularly inept not to have taken full advantage of their opportunities.

It is difficult to believe that when parasites succeeded in establishing themselves, they limited their geographical orbit to the Fertile Crescent and they must have followed when daughter civilizations grew up in France, Spain, Germany, Britain, India and China.

Unfortunately, very little is known about the early diseases of these countries, but pulmonary tuberculosis was probably present in India in 1,300 B.C., and smallpox, or a pustular infection resembling it, is referred to in very early Sanskrit writings. In China, malaria may have been active in 3,000 B.C. because the virtues of a drug, Ch'ang Shang, known to possess antimalarial properties, is referred to in the Book of Herbs.[54] Smallpox, too, may have been prevalent there in the millennium immediately preceding the birth of Christ. Leprosy is also implied in a reference in the Su-yen dating from about 400 B.C.[55] With the exception of a Neolithic skeleton showing a tuberculous lesion of the

spine, unearthed near Heidelberg, little or nothing is known of the history of infectious disease in the great mass of the European continent away from the Mediterranean littoral.[50] Even less is known about the southern half of the African continent. Tuberculosis seems to have been unknown until the white man came, but smallpox seems to have been rife and Negro slaves are credited with introducing it, with hookworm and yaws, into America.

Thus however free of infection Palæolithic Man may have been, there seems no doubt that Neolithic Man and his successors in the Fertile Crescent and the neighbouring countries were thoroughly seeded with parasites producing diseases closely resembling those of their descendants at the present time.

How these parasites were developed and how they reached Neolithic Man can only be conjectured but the intensive study that bacteria and other parasites have received during the past half century enables us to make certain suggestions. In the first place, there is certainly no evidence that they appeared as a result of spontaneous generation, or that they are the consequence rather than the cause of the illnesses they produce. We must, therefore, assume that they have come by some process of evolution involving mutation, adaptation and natural selection, from ancestral forms.

The immediate ancestors of parasites which produce disease in a warm-blooded animal such as Man cannot very well have been free living species because the metabolic activities of organisms capable of survival and multiplication in the waters of the earth or the earth itself are not, in general, suited to their growth in the tissues of warm-blooded species. Nevertheless, this step must have been taken at one

time, probably soon after mammals made their appearance, and therefore long before the development of Man himself.

It is therefore probable that some at least of the parasites producing disease in human beings had undergone most of their development in mammals. Then at some comparatively recent date they transferred their activities to Man. In support of this, there is the striking fact that many human pathogens have close relatives which produce somewhat similar forms of infection in warm-blooded creatures such as animals or birds. Thus, the particular variety of *Mycobacterium tuberculosis* which is responsible for most cases of the disease in Man is a human parasite which is not found in animals who have no contact with Man. It has many points of resemblance to three relatives, one of which (the bovine form) produces the disease in cattle, another producing tuberculous infection in voles, a third being responsible for infection in birds. But by means of tests such as their virulence for rabbits and the appearance of their colonies on culture media, all four varieties can be shown to possess characteristics of their own.

The *Salmonella* which produce typhoid and paratyphoid fever are also human parasites, seldom, if ever, producing infection in animals. But many species of *Salmonella* are parasites of oxen, pigs or birds. Some of these species closely resemble those responsible for the purely human infections, typhoid and paratyphoid fever.

Corynebacterium diphtheriae, the cause of diphtheria in Man, is a very distinctive organism in appearance, in the pathological process it produces, and in its ability to produce a powerful poison or toxin. It, too, is a human parasite. But there are also a number of related species such as *C. ovis* responsible for an ulcerative infection in horses, *C. pyogenes*

the cause of suppuration in cattle, pigs and sheep, *C. equi* which infects foals, *C. renale* the cause of some forms of pyelitis in cattle and *C. murium* a pathogen of mice. Some of these organisms, particularly *C. pyogenes* and *C. ovis*, even resemble *C. diphtheriae* in being able to form a toxin.

Some of the viruses, too, possess relatives producing disease in animals. One of the best examples is that which causes smallpox. This virus is a comparatively large, square-shaped body and similar organisms have been found in animal infections which resemble human smallpox in a number of respects. One of the most instructive is ectromelia or mouse pox, but there are also pox diseases of sheep, goats, rabbits and cows.

It is hardly necessary to pursue these matters further except to point out that both the protozoa of malaria and the spirochaetes of human infections are frequently related to varieties from infections in animals or birds.

In view of the close similarity between the varieties infecting Man and those infecting animals, it is a plausible hypothesis that at some time in the past Man acquired these organisms from an animal host but, in the intervening years, the organisms have become so adapted to human beings that they have acquired new properties or lost those they formerly possessed. In this way they have become distinct species demonstrably different from those infecting animals at the present time. It is equally possible that the animal strains themselves may also have altered very considerably in this way increasing the divergence between the two lines.

That micro-organisms can adopt a new host such as Man in this way is by no means outside the range of possibility. Several instances are known in which an animal parasite has been transferred to Man and then behaved as

a human parasite, passing from human being to human being in series without its true host taking part in the proceedings at all. Perhaps the most instructive example of this is plague. This is not really a human disease. It is a disease of rats. Its causative organism, *Pasteurella pestis*, makes its home in rats and Man is not normally infected by it, nor is he a carrier. But if he is bitten by a flea from a plague infected rat, he gets the disease and usually very badly, as bubonic plague. When he has this form of the disease, it is improbable that he can transmit his infection to other people. But he may get pneumonic plague. If this occurs, and it does not happen very often or in all epidemics, he can then transmit his infection only too easily to his attendants by means of his sputum. And they, in their turn, can transmit the infection to others. In this way, what is fundamentally a disease of the rat can behave as a human disease. It is highly probable that it was this change from the more normal behaviour of the parasite which was the cause of the terrible mortality in Europe during the Black Death.

The virus of yellow fever may behave in somewhat similar fashion. Its main habitat in Nature is not Man but certain species of monkey. From them, it can be transmitted to human beings by *Haemagogus* mosquitoes. This is the mode of causation of what is known as jungle yellow fever in the forests of South America. But once the virus has reached a human being, it can then be transmitted to other human beings by means of *Aedes* mosquitoes which tend to live in the neighbourhood of human habitations. And it was by this agency that so many lives were lost in the early history of the Caribbean.

The rickettsiae which cause epidemic typhus fever seem

to have gone a stage further. *R. mooseri* produces infection in rats and is transmitted from rat to rat by fleas. Man may become infected if he is bitten by an infected flea. But *R. mooseri* is very closely related to *R. prowazeki*. Its host is Man and it is transmitted from man to man by lice, producing what is known as epidemic typhus fever in the process. Because this form of the disease (which is slightly different from endemic typhus produced by *R. mooseri*) seems to have been very unusual before the fifteenth century, Zinsser has suggested that at some time in that century, the new species, *R. prowazeki*, developed from *R. mooseri*, at the same time adopting Man as its permanent host and lice as its intermediate host and transporting agency.

Although an animal origin can be invoked to explain the presence of some of our parasites, many of them do not possess relatives which infect animals. Their origin is even more conjectural. But it is possible that some have come from human commensals. The genus known as *Neisseria* contains several species which are commensals in the human throat and genital tract. Two species, *N. meningitidis* and *N. gonorrhoea*, produce cerebrospinal fever and gonorrhoea respectively. No possible animal source for either of these organisms is known.

Although we have been able to put forward suggestions for the advent of some human parasites, possible sources for others cannot even be guessed at. This particularly applies to many of the viruses. Those which cause the common cold, poliomyelitis, measles, mumps, to mention only four, possess no known relatives responsible for any similar forms of infection in animals. Their origin must therefore remain in doubt.

Even when a parasite has adopted Man as its permanent

host, it must not be assumed that it is unlikely to undergo alteration in the course of the centuries. Micro-organisms show remarkable powers of mutation and adaptation, not only in the test tube but in their natural hosts as well. Many examples of this could be quoted. When, for instance, penicillin was first introduced very few strains of *Staph. aureus* were resistant. But probably as a result of widespread use of the drug, strains which are resistant have not only emerged from their former obscurity but are now present in the noses of a high proportion of the nursing and medical staffs of our large hospitals. This reaction on the part of a parasite to a known stimulus is perhaps understandable. But other alterations have occurred, either spontaneously or at any rate without our knowing their causation. Thus the virus responsible for a form of influenza known as influenza A was first isolated in 1933 and in the epidemics of the succeeding years, the same variety was always isolated. But between the outbreak in 1945 and that in 1947, some change took place in the virus which rendered it demonstrably different and, in the succeeding years, it has been this altered form, and not the original variety, which was isolated from the patients.

The bacillus which causes diphtheria has also shown somewhat similar tendencies although the tempo has been considerably slower. The variety common in Europe up to the late 1920's was that which possesses certain characteristics (colony appearance and fermentation reactions) by which it is recognized as the *mitis* form. This variety produced a disease easily cured by antitoxin and prevented readily by inoculation with toxoid. But in 1927 a new form of the disease in which antitoxin was virtually powerless, and immunization of little value for prevention, was recognized

in Berlin. The organism responsible had new characteristics and is known as *gravis*. Since then it has spread to other European countries but has so far only appeared sporadically in America. There seems little doubt that whatever its origin, it is certainly a hitherto unknown and rather more dangerous variety of the organism.

These observations suggest that the bacteria and viruses responsible for human infection can undergo alterations which are permanent in character while living in the body of their natural hosts. But although the alterations were not so marked as to suggest that a change in species had occurred, even this is not outside the range of possibilities.

The *Salmonella*, for instance, consist of rod-shaped organisms which possess hairs or flagella on their surfaces. The chemical composition of the substances which make up the bodies and the flagella can be recognized by certain delicate tests which it is unnecessary to describe. It is on the presence or absence of these substances that demarcation of the species within the genus depends. By methods so far only employed in the test tube but which could quite well be employed in the body, it has been found possible to transfer the ability to produce one or more of these chemical substances to strains which previously did not possess this ability. In this way, what are virtually new species of *Salmonella* have been produced.

Consideration of all the available evidence forces us to the conclusion that Man did not bring many of his pathogenic parasites with him in the course of evolution. Whence he obtained them is still a matter for conjecture, but some may have come from other warm-blooded hosts such as mammals or birds, some may have been derived from commensals he may have brought with him, but for the

origin of many, we cannot even hazard a guess. In the course of the centuries, largely as a result of mutation, variation and natural selection, many of these parasites have probably undergone considerable modification and may well be very different from their ancestral forms. Indeed, they are probably in a state of constant flux. Their virulence may rise or fall; they may acquire new properties or lose some they already possess; new pathogens may be created from other less dangerous organisms; pathogenic parasites may lose the ability to produce disease; and they may even acquire the ability to parasitize and produce disease in hosts who have hitherto escaped their attentions.

Because processes of this nature have probably been going on all through the period of Man's development, parasites potentially pathogenic for Man may well have been available from very early times, somewhere in the world. But before they could become important in human affairs, it was first necessary for them to find human beings to act as hosts. This step may well have been relatively easy, but the second step, permanent settlement in human beings, was probably much more difficult. For this to be successful, a large population is generally necessary, and in this respect, Palæolithic Man was very inadequate. It was not until he had learnt to produce his own food, and to live in permanent settlements, that he gave pathogenic parasites their opportunity.

It is therefore probable that the real history of human infectious disease does not go very much further back than 18,000 to 6,000 B.C. when the Neolithic Period of Man's development began. At first, its geographical extent was probably limited to the Fertile Crescent and its near neighbourhood but in course of time, as the population of

the European-Asian-African land mass increased and communications improved, infectious diseases gradually extended their spheres of activity.

Accordingly, infectious disease, much of it closely resembling that known today, was well established at the start of the Christian era over large areas of the Old World, and during most of the succeeding two millennia, Man himself did almost everything he could to propagate it. Imperial Rome, thanks to the care it bestowed on its water supply and the disposal of its sewage, may have inhibited the organisms responsible for enteric and dysentery, and its love for bathing may have discouraged the breeding of lice and other body vermin to carry plague, typhus and relapsing fever, but the crowded *insulae* in which the poor of Rome and its daughter cities dwelt were admirably adapted for the spread of many other forms of infection. Malaria, too, was widespread and although the close proximity of the Pontine Marshes may have appeared to be of little importance to Romulus and Remus, their mosquitoes functioned for many centuries, as transporting agents for the disease said to have been brought to the city by Hannibal's men.

In the centuries which followed the collapse of Rome, matters probably became very much worse, and certainly, by the time of the Renaissance, Man had succeeded in evolving for himself an environment which was almost ideal for the propagation of parasites. Even the better parts of a mediaeval city seem to have closely resembled some of the worst slums that ever existed. The houses were dirty, sunless and ill-ventilated. Their inhabitants were quite as dirty and equally ridden with vermin. Water was scarce and of very doubtful purity. Household refuse of all kinds, blood and offal from slaughter houses, and manure from the large

number of pigs, horses and fowls, which invariably found a home within the walls, were all allowed to collect because there was no organization for their disposal.

If there were any facilities for the disposal of the excrement of the human population, these usually took the form of privies or cesspools in the basement of the buildings. There was always a distressing tendency for them to overflow; even as late as the seventeenth century, Mr. Pepys, at that time a person of some importance, had to complain to his neighbour in Seething Lane because the latter's cesspool was leaking into his basement.

The roads and lanes, too, were generally offensive. In Verdun during the year 1792, "every day, refuse of all kinds was thrown from each house out into the street—the evacuations of men and animals, rubbish and garbage—and there it mixed with the mud, liquefied and rotted through the action of the rain. The officials in charge of street sanitation were powerless. All this filth emitted a foul odour when a carriage drove through it and one often saw people seized with convulsions, overcome by vomiting or even asphyxiated, while crossing the streets."[57]

In the big industrial towns which sprang up following the Industrial Revolution, things were far worse. Large numbers had come into them from the country to work in the new factories. There being no control over housing, the rents were frequently too high to permit of even large families occupying more than one room. The water supplies of these slums were very deficient; piped water costs money, and sanitary conveniences either did not exist or were hopelessly inadequate. In Leeds, for instance, there were three parallel streets housing 386 individuals whose only sanitation consisted of two small privies. Liverpool was almost worse

with a population of 20,000 living in cellars which had no sanitation whatever. Even London had 7,095 persons in 645 houses which possessed only 33 privies.[58] New York was little better with 18,456 persons living in 8,141 cellars.[59]

There was no particular reason for this sort of thing in the cathedral cities of England. Exeter, for instance, far away in the west, and surrounded by a pleasant agricultural countryside, was probably as clean as any city in the Europe of the period. But when cholera came to it in 1832 and a district committee was appointed to enquire into the less well favoured parts of the city, they made some painful discoveries. According to Dr. Shapter,[60] their report "details a state of things beyond all belief—to enter upon these would be tedious if not disgusting, suffice it to say, they speak of dwellings occupied by from five to fifteen families, huddled together in dirty rooms with every offensive accompaniment; of slaughterhouses on the Butcher Row with their putrid heaps of offal; of pigs in large numbers kept throughout the city; of poultry kept in confined cellars and outhouses; of dung heaps everywhere;—one cottage was visited in which the accumulated filth and soil of thirteen years was deposited, and esteemed so valuable a property that its removal was strenuously resisted. To add to all this, in many parts, the visits of the scavengers took place but once a week. While the general characteristics of the city were those of health and pleasantness, such was the prevailing condition of the lower and neglected portions. The early proceedings of the Board of Health indicate that this was felt to be most disgraceful and unsatisfactory; and an expression of compunction is not altogether wanting for the too obvious neglect, herein displayed, of the wants of the poor. Actuated by feelings of this nature and dread of the

impending pestilence, the public corporation combined with the Board of Health to abate and remedy these evils."

Thus, whether by reason of ignorance, indifference, stupidity or the opposition of vested interests, the cities of Europe were, until comparatively recently, admirably adapted for the propagation of parasitic infection. There seems no doubt that the parasites took every advantage of their opportunities. Such diseases as smallpox, enteric, diphtheria, erysipelas, malaria and severe forms of scarlet fever, which are almost unknown in Europe or America at the present time, were constantly present together with far more cases of tuberculosis, dysentery and syphilis than are ever seen nowadays. There were, in addition, frequent epidemics of such diseases as plague, cholera and typhus, some of which were of great severity.

Deaths directly due to these diseases formed an appreciable part of the total mortality every year. Examination of the Bills of Mortality which give the probable reasons for the death of the citizens of London in the seventeenth and eighteenth centuries,[61] and the records of the General Register Office which provide similar data for the nineteenth and twentieth centuries,[62] shows clearly that about half the deaths during three of these centuries were due to some form of parasitic infection. Taking the five years 1647 to 1651, for instance, 49 per cent of the deaths were caused by such conditions as "consumption and cough", "ague and fever", "cold and cough", "quinsy and sore throat", "flux and smallpox". During the years 1741 to 1745, 68 per cent of the deaths were evidently due to "ague", "bloody flux", "cough and whooping cough", "malignant fever, scarlet fever and purples", "flux" and "consumption" together with measles, smallpox and infantile

even now, not far short of three-quarters of all the deaths which occur amongst inhabitants of the less well-favoured parts of the globe are due to parasites.

Thus, whatever may have been the difficulties human parasites faced during the early stages of Man's development, it is clear that the men who lived in the great European-Asian-African land mass have been severely afflicted by them for well over 3,000 years. It is no exaggeration to say that at least half and probably more of all the deaths during this long period was due to them. Their impact was undoubtedly greatest on the children, and uncounted millions must have died in the course of these centuries. Man did almost everything he could to assist the parasites and eventually evolved an environment which was ideal for their propagation. This process reached its apogee during the Industrial Revolution, since when much has been achieved in limiting their activities. In consequence, it is becoming increasingly difficult to die of infection, even if one cannot always escape it altogether. But this requires a vast State-sponsored apparatus and in many countries parasites are still as active as they were in Europe a hundred years ago.

CHAPTER THREE

PARASITES AND PESTILENCE

A dreadful plague from angry Juno came
To scourge the land that bore her rival's name.

OVID.

IN THE PRECEDING chapter we have, for the most part, been discussing what bacteriologists call endemic infection: that is, the infections which occur in the community more or less all the time and which do not alter very much in severity or in the numbers infected from year to year or even from century to century. But while this is, or was, bad enough, abnormal outbreaks of infectious disease which are generally called epidemics appear at irregular intervals. There is no particular standard by which we can judge how abnormal the outbreak must be to lift it out of the monotony of the endemic into the drama of an epidemic. It is mostly a matter of relative values, for which reason one hundred cases of poliomyelitis in this country, which seldom indulges in epidemics of any size, may create considerably more perturbation than a thousand or even ten thousand cases of smallpox in China, where this disease has been part of the national morbidity for many years.

Nevertheless, it is as well to remember that some diseases seldom become epidemic. Tuberculosis and the common cold, measles, mumps, diphtheria and whooping cough, in fact all the common parasitic infections, are endemic diseases in England, seldom varying very much in their incidence from year to year. But an outbreak of typhoid,

cholera, plague or smallpox would, quite definitely, constitute an epidemic because these diseases are normally unknown or very unusual.

The particular chain of circumstances which may precipitate an epidemic is not always the same and there are at least five ways which can be named.

(1) Some epidemics are due to the importation of a parasite into a population previously unacquainted with it, and therefore without immunity. Nearly all the great epidemics of history belong to this category, such as the Black Death in Europe in 1345, cholera in countries outside India in 1817 and the following years, smallpox amongst the North American Indians in 1633, and measles in the Faeroe Islands in 1846 and in Fiji in 1875.

(2) Some are due to the importation of a large number of susceptibles into an area in which there is a resident parasite causing only endemic infection amongst the native population. This is merely a reversal of what occurs under (1) above. It is the principal cause of epidemics amongst soldiers. The outbreaks of dysentery which played so prominent a part in the Crusades, the yellow fever which left Napoleon with only 3,000 men out of the 25,000 he had sent to win a West Indian Empire, and the enteric fever which wreaked such havoc with the British Army in the South African War, all belong to this category.[1]

(3) Some epidemics are due to a sudden change in the facilities for the transmission of a parasite which has been resident in the community for some time but has been largely impotent because it cannot get about. In the typhoid epidemics in Croydon in 1937 and in Bournemouth in 1936, a carrier who had previously done no harm managed to infect the water and the milk supply respectively. Epidemic

typhus too must be included in this category because it depends on the louse for its transmission. It is only when the population becomes unusually lousy that an epidemic is likely to occur. It is for this reason that typhus is unusual in time of peace but comes into its own in war or civil commotion. This was the genesis of the typhus epidemics in Serbia in 1914–15 and in Russia in 1918–23. Malaria is also transmitted by insects and the number of cases generally bears a marked relationship to the number of mosquitoes in the vicinity. Epidemics of malaria have therefore occurred when unusually large numbers of mosquitoes have made their appearance. This occurred in Ceylon in 1934–35 when a serious drought dried up the rivers and left pools of stagnant water admirably adapted for the hatching of *Anopheles*.[2]

(4) It is probable that some epidemics may be due to an alteration in the character of the parasite, rendering it slightly different and more virulent than was the strain which had previously been present in the community. Such an alteration enables it to produce infection and possibly death amongst individuals who would have escaped prior to this alteration.

It is now considered probable that the two pandemics of influenza in 1889 and in 1918 were due to a sudden mutation of this character. There is also a possibility that the unusually severe form of diphtheria which in 1943 produced a million cases of the disease in Europe alone, was due to the arrival on the scene of a more virulent (*gravis*) strain of the diphtheria bacillus than the *mitis* strain of the same organism which had previously been the only variety known to produce the disease.

(5) It is possible, but very difficult to prove, that starvation may reduce the resistance of a population to such an

extent that endemic parasites may produce a sufficient number of new cases to constitute an epidemic.

Pulmonary tuberculosis increased considerably in Berlin during the later years of the war. So much so that the death rate increased from 76 per 100,000 persons in 1938 to 268 per 100,000 in 1945.[3] While this may have been due to overcrowding in air raid shelters, and similar factors (in which case the epidemic should be classified under (2) above), it is equally possible that malnutrition had much to do with the increase in the death rate.

Dysentery is also common in starving populations, but here again it is not possible to say whether it is due to malnutrition, or to the overcrowding and the total lack of hygiene which generally accompany such conditions.

Thus, a number of different sets of circumstances may produce an epidemic, but by far the most important is the first of those listed above. Because of the control now exercised over the public health in all the countries of the West, epidemics of any severity very seldom occur, but in the past they were common, highly lethal, and sometimes devastating in their effects.[4]

Epidemic disease was, for instance, well known to the Israelites. There were the ten plagues of Egypt, the plague of Ashdod, and that fearful outbreak of pestilence that came to the army of Sennacherib and "smote in the camp of the Assyrians an hundred fourscore and five thousand: and when they arose early in the morning, behold, they were all dead corpses." Nor must we omit the plague of David which came when he was faced with a choice of evils comprising seven years of famine, three months of fleeing before his enemies, and three days of pestilence. Choosing the last, he lost seventy thousand of his people.

The epidemiology of Greece is much less exciting. There is little to record except for the outbreak which ushers in the Iliad, in which

"First on the mules and dogs, on man the last,
Was poured the arrowy storm: and through the camp,
Constant and numerous blazed the funeral fires",

and the great Plague of Athens, described in deathless prose by Thucydides.

Not so Rome. Its acquaintance with epidemic disease began in 707 B.C., only forty-six years following the foundation of the city. There were further outbreaks in 640, 514, 473, 461 and 451, in the last of which all the slaves and half the free population are said to have perished. There were further outbreaks in 435–30, and five more at intervals in the fourth century. There was an outbreak in 295, and a second in 293, during which ambassadors were sent to Epidaurus and brought back with them one of the snakes from the shrine of Aesculapius. This may have been a wise move because it was not until 212 that the next epidemic occurred, to be followed by others in 183, 180, 176 and 175, which is the last recorded by Livy.

It is unfortunate that we possess insufficient information to give even a tentative diagnosis of the disease responsible for any of these epidemics. Nor do we know very much more about the series of epidemics which came during the reign of Marcus Aurelius, or those which added their quota to the miseries of the middle years of the third century A.D. Indeed, we have to wait until the sixth century before we can name an epidemic due to a recognizable disease. This was the outbreak of bubonic plague which afflicted most of the then known world during the reign of Justinian, and

which seems to have been rivalled in severity only by the Black Death.

The Dark Ages are even darker to the student of epidemics than to the historian, for we know very little about what happened during them. But there seems little doubt that while plague was probably absent, typhus was rife and smallpox may have been on the increase. We also know that most of the crusading armies were destroyed by vitamin deficiencies and dysentery. But it is the importation into Europe of plague in the form of the Black Death during the middle years of the fourteenth century that marks the beginning of our more accurate knowledge of epidemic disease. In the space of about five years from a third to a half of the inhabitants of the known world lost their lives from this one disease. This was but the beginning of 400 years of more circumscribed outbreaks of the disease in the cities of Europe.

In the closing years of the fifteenth century came syphilis, probably brought by Columbus from the western hemisphere to a population previously unacquainted with the disease. It therefore behaved, for the first and last time, as an epidemic disease and in the short space of six years spread to every country in Europe as a very severe and quite frequently fatal infection. About the same time, England stood alone in suffering from five visitations of a disease known as the English Sweat, probably introduced, despite its name, by Norman soldiers in Henry Richmond's army which landed at Milford Haven. Although it came five times in the years 1486, 1507, 1518, 1529 and 1551, and was described in detail by one of the greatest of the mediaeval physicians, John Caius, we are still uncertain of the diagnosis. The Picardy Sweats, about the same time, may or may not

have been typhus but there is no doubt that they too were virulent and dangerous infections.

In the seventeenth century, the chief epidemiological event was the series of outbreaks of plague and typhus which added their miseries to the starvation and depopulation of much of the continent of Europe in that orgy of horror known as the Thirty Years War. But in the western hemisphere, it was smallpox which, infecting the North American Indian tribes, so weakened them that they were unable to resist the mounting tide of settlers from the Old World.

The eighteenth century was distinguished by the rapidly increasing importance of yellow fever in the West Indies, Central America, and the southern United States. But in Europe it was smallpox which had become gradually more virulent and lethal. The nineteenth century saw the upsurge of cholera. Previously limited in its operations to a small area of India, it burst forth in five great pandemics in which it encircled the globe and reached countries which from the beginning of time had been completely free of it. During this century, too, typhus had an important part to play—in Russia where it harried Napoleon in his retreat from Moscow, and in Ireland where it added to the miseries of that unhappy country. Despite the growing knowledge of the habits of parasites, the twentieth century has already contributed an impressive share to the annals of epidemiology. There was the great pandemic of influenza in 1918–19, the fearful epidemic of typhus during the Civil War following the Communist Revolution in Russia, two major outbreaks of plague in China, and localized but severe epidemics of cholera in India.

This very brief survey has referred only to the more

outstanding outbreaks but there were few years in all these centuries in which some more circumscribed but equally severe epidemic did not occur somewhere in the world. On the whole, smallpox, typhus, plague, cholera, influenza and dysentery have been responsible for the most severe of these epidemics, and we shall therefore refer in a little more detail to these six diseases.

Smallpox

The early history of smallpox is very obscure. It would seem to have been prevalent in India from remote antiquity. A disease characterized by a pustular eruption is referred to in some of the oldest Sanskrit writings. The Brahmins invoked the aid of particular deities for protection against this disease. It is also possible that it was prevalent in China as long ago as the dynasty of Tsche-u, that is, some time between 1122 and 246 B.C.[5]

Egyptian mummies have been found with rashes resembling those of the disease. It is also possible that it occurred amongst the Hittites, since cuneiform tablets found in Asia Minor record a severe epidemic which Professor Wynn considers may have been smallpox.[6] The epidemic in question is of some historical importance since most of the Hittite army and a large proportion of the civilian population, as well as the King and the son who succeeded him, died during it. This crippled them to such an extent that they were overwhelmed by the Acheans and Assyrians, bringing to a sudden end a civilization which had flourished for a thousand years.

A severe pandemic that occurred in the middle of the second century A.D., known as the Long, or Antonine, Pestilence, may also have been smallpox. For the clinical

details of this outbreak the only authority is Galen, and mostly in the form of scattered references. According to him there appears to have been an acute inflammatory condition of the throat, resembling erysipelas or herpes. There was also severe inflammation of the gastro-intestinal tract, with stools at one time yellow or red and at other times black with dried blood. There was tenesmus, diarrhoea, and pain on defaecation, particularly in those patients who died. There was cloudy, evil-smelling urine, with ulcers in the bladder. While these symptoms are suggestive of smallpox, the diagnosis usually rests on the appearance and distribution of the rash, and here Galen is anything but explicit. Some of the patients had small phlyctens or ulcers which became so painful that they were unable to bear the weight of the bed clothes on them. Other patients had patches of erysipelas, some rashes resembling phlegmons, some herpes, some lichen, and some an efflorescent anthrax, while some had rashes resembling leprosy.

It cannot be said that this is in any way a classical description of smallpox. Indeed, it is much more probable that while smallpox may have been rampant, other diseases played an important part as well. But one thing seems certain. The disease or mixture of diseases did not include bubonic or pneumonic plague. In spite of this, historians are singularly unanimous in describing it as "the true oriental plague" or "the bubo plague".

It[7] seems to have started in A.D. 165 towards the end of the Parthian war which had broken out during the joint Imperium of Marcus Aurelius and Lucius Verus. Roman troops had been besieging Seleucia on the Tigris and when the city fell, they interfered in some way with the statue of Apollo. This ill-advised tampering with the god of pestilence

reaped its own reward, for a very infectious and highly lethal disease soon appeared and wreaked havoc with the Roman troops. The war ended about this time, and the disease seems to have accompanied the returning legions in their march over the Anatolian uplands, through the defiles of the Balkans, and down the long straight roads to Rome itself. In this way, a very dangerous disease was disseminated with superb efficiency over a large part of the Roman Empire.

In consequence, the Triumph in the spring of A.D. 166 was marred by the simultaneous presence of the disease in the city of Rome. And if this were not enough, there was also a shortage of corn. It is therefore not very surprising that before long the dead were so numerous that Marcus Aurelius had to requisition carts and wagons to dispose of them, giving them the dubious honour of a public funeral.

There seems little doubt that it was a persistent disease with a high mortality and a wide sphere of activity, for it remained for fifteen years, and according to Orosius it "so devastated the whole of Italy that villas, towns and lands were everywhere left without inhabitants or cultivation and fell into ruin or relapsed into wilderness". We know very little of its travels beyond the bald statement that it spread from "Persia to the shores of the Rhine". But it is highly probable that it actually went much further, and may even have reached China, because a disease closely resembling smallpox was described by Ko Chang during the following century.[6]

But what makes this epidemic so important is the fact that its arrival coincided with an outburst of activity on the part of the German tribes north of the Danube. For many years these tribes had been content to remain in their

damp and sunless forests without greatly troubling the prosperous and fertile empire to the south. In part, this may have been due, as Tacitus hoped it would remain so, to dissension between the tribes. But these feuds had evidently been patched up some time during the Parthian War, and the tribes were obviously bent on invasion. For a time they were kept at bay by the time-honoured expedient of bribery, but during the summer of A.D. 166, about the time the epidemic was getting into its stride, they crossed the frontier and swarmed into Rhaetia, Noricum and Pannonia (the Switzerland, Austria and western Hungary of the present day) captured 160,000 prisoners, and did immense damage to the cities and towns in these provinces. They probably remained there during the succeeding winter, but in the summer of A.D. 167 seem to have gone further afield, to the valley of the Save, into Dacia and, worst of all, across the Julian Alps to the Adriatic and the sacred soil of Italy itself, wrecking Opitergium and besieging Aquileia. Although the siege of Aquileia was raised the same summer and the invaders retreated from Venetia, the provinces north of the Alps seem to have remained more or less in their possession until the Marcomanni were smashed at Regensburg in A.D. 171, the Quadi in A.D. 174, and the war came to an end with the defeat of the Jazyges in A.D. 175.

Thus, a great empire with all its administrative machinery intact and its troops fresh from a successful war against Parthia, took at least nine years to free the invaded provinces from a horde of relative amateurs in the art of warfare.

There seems little doubt that the principal reason for the delay in finishing the business was the complete, or almost complete, paralysis of the Roman army by the epidemic.

Eutropius certainly stated that almost all the soldiers perished. Their numbers had to be made up, in part, by the conscription of slaves, gladiators and the brigands of Dalmatia, while the *diognitae* or police soldiers of Asia Minor were also mobilized.

For at least a year, the army was unable to advance into the invaded provinces because "the mustering of the troops at Aquileia served to concentrate the fatal sickness which had abated none of its virulence". Because his preoccupations were more medical than military, Marcus Aurelius therefore summoned Galen,[9] who, disliking heroics, had fled from Rome to Pergamum at the onset of the epidemic. To make closer contact with severe pestilence was the last thing that Galen wished, but a Roman emperor could still exact obedience from his subjects. Accordingly, Galen duly made his way to Aquileia. But despite the fact that subsequent centuries ranked him as the equal of Hippocrates, his resources were extremely slender; the lighting of large bonfires in the camp, and the administration of iron oxide to those who were ill, were, so far as we know, the most that he could do. Needless to say, measures of this sort were not likely to deter smallpox, and thus the first intrusion of medical science into warfare was without tangible result. Few things being more pathetic than a discredited expert on the scene of his failure, Galen retreated to Rome, and the epidemic was allowed to burn itself out.

There seems little doubt that the Germans were afflicted as badly as the Romans. Many dead bodies were found with no signs of injury. This was only to be expected; epidemic disease infects friend and foe alike. It is probably for this reason that the tribes did not go further afield, for there was evidently no one to stop them. Indeed, it took

three or four years merely to collect sufficient troops to allow Marcus Aurelius to advance into the invaded provinces, and establish his headquarters on the Danube, and it took several more years of hard fighting before Marcus Aurelius was able to take his Triumph on December 13, A.D. 176.

The ensuing peace was short-lived. The two Quintillii were soon complaining that they could not hold the frontiers much longer, and once again Marcus Aurelius set out for the north. But this time, with the epidemic almost over, there were few difficulties about a sufficiency of troops. The Germans were defeated with becoming celerity. Roman soldiers penetrated far beyond the Danube and for a time it seemed that a new province had been hewn out of the wilderness.

But epidemic disease had not yet finished with the Empire, for pestilence again broke out, and there is reason to believe that one of the first victims was Marcus Aurelius himself. He was succeeded by Commodus, who was anything but the man of the hour, and with little delay concluded a peace with the German tribes, giving up all the territory the Roman armies had gained, and even allowing the Germans to return to the line of the Danube and to settle the devastated lands on its southern bank, while their young men were conscripted to cool their military ardour in other parts of the Empire.

Although these expedients have been condemned by historians, it should be remembered that the epidemic had recurred about this time, and with their previous experiences in mind, the Romans may have hesitated to risk further hostilities with an army which in the previous outbreak had persisted in melting away before it ever saw the enemy.

But the opportunity to push the frontier northwards to the Carpathians and away from its weakest point on the Danube was irretrievably lost, and the history of the succeeding centuries consists of little beyond the attempts to hold the frontier there. They failed, and for a host of reasons, but it is probable that the Decline and Fall began one day in March, A.D. 180, when an ageing, disappointed man lay dying at Sirmium or Vindobona.

Other than its possible participation in the Antonine Pestilence, and the death of Diocletian from a disease strongly resembling it, there is very little evidence that smallpox was at all widely dispersed in Europe during the greater part of its domination by the Romans. It seems to have been taken to Mecca by the Abyssinians during the elephant war of A.D. 370, and it may have been widely prevalent in France and Italy during A.D. 570. But it was not until the Arabs started on their astonishing career of conquest that the disease was thoroughly disseminated over the Mediterranean littoral. That enterprising race had become infected by an Abyssinian army in Syria and took the infection with them as they spread through northern Africa and western Europe during the seventh century A.D.

But it was not until the eleventh and twelfth centuries that smallpox became an important disease on the European continent. At that time it seems to have been relatively mild, but it gradually became commoner and more virulent, until it was at its worst during the eighteenth century, when in the space of about fifty years it killed no less than eleven members of the Imperial House of Austria. Other dynasties were similarly afflicted; it killed Louis XV of France, William II of Orange, James I of Germany, Peter II of Russia, Queen Mary, consort of James II of England, Henry,

Prince of Russia, two Empresses of Germany, a Queen of Sweden, two children of Charles I and two of James II of England.[10] Their subjects were little better off; for many years, London seldom had less than 1,000 deaths each year, and in some it was as high as 5,000.

It was, however, in the New World that smallpox showed its true mettle. Appearing first in Cuba in 1507, probably imported by Negro slaves from Africa, it reached Haiti in 1517 where it was strategically placed for invasion of the mainland. Its opportunity came during the conquest of Mexico by Hernando Cortes in 1520.[11] With a total force of 110 mariners, 553 soldiers, 10 heavy guns, 4 falconets and 16 horses, he had landed on the strip of sand where Vera Cruz stands to-day. Having first destroyed his ships in order to discourage unnecessary retreats, he overcame all opposition and occupied Tenochtitlan (Mexico City), the capital of the Aztec Empire.

The main objective of the expedition having been the acquisition of gold by theft or any other means, and this having been accomplished with surprising ease, there seemed some hope that the Aztecs might then be left alone. But, exasperated by the entirely unnecessary massacre of their nobility, the Aztecs revolted, and Cortes not only had considerable difficulty in extricating his army from Tenochtitlan, but lost the treasure in the process. If this were not enough, a rival claimant in the person of Panfilo Narvaez appeared about the same time, that is on April 23, 1520. Narvaez was quickly disposed of, but his appearance on the scene had had one unfortunate result. A Negro slave had brought smallpox. The inhabitants of Cempoalla, near the coast, took to the disease with avidity. It soon reached Tlascala, without diminishing its severity with the increase

in altitude, while the chances of survival of its victims were noticeably lessened by the fact that they insisted on total immersion in cold water in order to diminish their fever. In a short time it was "sweeping over the land like fire over the prairies, smiting down prince and peasant, and adding another to the long trail of woes that followed the march of the white man".

There can be no question of the severity of the disease or its effects on the unfortunate inhabitants. Maxcica, the old King of Tlascala, died in the middle of December after a death-bed conversion to Christianity. Cuitlahuac, Montezuma's successor to the Aztec throne, had died at the end of October. Their subjects followed them in large numbers; "they perished in heaps like cattle stricken with the murrain". De la Condamine estimated that at least half of the three and a half million inhabitants died of the disease.

When, therefore, Cortes set out to reconquer Mexico on December 28, the ground was well prepared for him. Even so, it was a considerable time before the struggle was over; but on St. Hypolite's Day, August 15, 1521, the Aztec empire came to an end. But one cannot help suspecting that the real Conquistador was not Cortes, it was smallpox.

The Red Indian tribes of North America succeeded in escaping the disease for about a hundred years. But when it came, they "fell sick of ye small poxe, and dyed most miserably; for a sorer disease cannot befall them; they fear it more than ye plague; for usually they that have this disease have them in abundance, and for want of bedding and living and other helps, they fall into a lamentable condition, as they lye on their hard matts, ye poxe breaking and mattering, and running into one another, their skin

cleaving (by reason thereof) to the matts they lye on".[12]

The epidemic seems to have started in Massachusetts and Connecticut, which were infected in 1633 and 1634 respectively. It reached the Montaignais, Hurons and Iroquois, who lived on the St. Lawrence and the Great Lakes, only a year later. All were very severely infected and some of these tribes, notably the Hurons, were wiped out.

The Indians of the Middle West seem to have remained free until 1730, when the Sioux, the Snakes and the Piegans were infected, between one half and one third of the population dying.[13] Only three years later, in 1733, the disease reached Greenland, and the Esquimaux were quite as severely infected as the Indians to the south, so much so that there were few survivors.[14]

There seems little doubt, therefore, that smallpox played a more important part than is generally realized in permitting the colonization of the American continent by the white man.

When it was fully realized at the end of the eighteenth century that vaccination was a sure protection against smallpox, the disease began to recede in Europe as an important cause of death and disfigurement. But despite the fact that Edward Jenner, cast in bronze, duly appeared in 1850 to watch over the nursemaids in Kensington Gardens, the disease continued to smoulder in all the big cities of Europe, for in spite of his elevation to the ranks of London statuary, a large proportion of the population of Europe continued to neglect vaccination. It is not therefore very surprising that beginning in 1868 and lasting until 1873, there was a severe outbreak of the disease which infected places as far apart as Dublin, Vienna and St.

Petersburg. In England, the death rate reached 1,000 per million in 1871 with London as high as 2,421. In Vienna it was 5,369 and 10,750 in Hamburg.[15]

This was its last fling. Legislatures were finally persuaded that it was a disease which needed more than half measures for its control. Vaccination was made compulsory in many European countries, and by the end of the century there was very little, if any, smallpox in Europe.

So much for classical smallpox. But there is also a much less severe form of the disease. First noted in South Africa in 1895 and again in Brazil in 1910, where it produced no less than a quarter of a million cases, it was named Alastrim by the Brazilian natives, signifying a disease which spreads from place to place. There is little doubt that it is a form of smallpox, and recent researches by Professor Downie have established the fact that its virus is a very close relative of that which causes smallpox. But it is nothing like so severe, so mutilating or so lethal, and fortunately it seems to breed true, showing little tendency to change into the more virulent variety.

The disease seems to have travelled far and wide—to Switzerland, Holland, the Azores and Australia.[16] In this country it first appeared in East Anglia during 1919[17] and continued to spread. In one year (1927) no less than 14,764 cases of the disease were reported in England and Wales alone. But in the years that followed it slowly receded and by 1935 it had gone. With the exception of a small outbreak in Lancashire in 1953 it has not reappeared. But the severe, highly lethal form of the disease has been imported on several occasions. Nevertheless, recent legislation has abolished all compulsion in regard to vaccination! Let us hope that our quarantine service continues to function with

efficiency, for a dangerously large proportion of the population of these islands is now susceptible to smallpox.

Plague

It is unfortunate that many writers, both ancient and modern, employ the term plague to denote any severe pestilence. It should be reserved for outbreaks of a very distinctive disease due to a specific organism and occurring in two forms, bubonic plague and pneumonic plague. None of the pestilences mentioned in the Old Testament or, for that matter any of those recorded before the birth of Christ, bear very much resemblance to plague. Indeed, the earliest reference to the disease is by Rufus of Ephesus, generally believed to have lived during the early years of the second century A.D. It is stated that a disease occurred in Libya, Egypt and Syria, in which there occurred buboes that failed to suppurate—a usual occurrence in plague. The first clear and undoubted account of the disease comes comparatively late in history, in the sixth century A.D., when an outbreak, frequently referred to as the Plague of Justinian, made its appearance. Three accounts of the disease survive. Evagrius of Antioch[18] wrote his at the age of 58 after he had been through four separate outbreaks, the first at the age of six when at school, during which he himself was infected. He escaped in the subsequent visitations, but lost his wife, several children, one grandchild, many relations and several servants. Agathias was in Constantinople during the second outbreak in A.D. 558 and his account is much shorter.[19] But most of our information comes from the *History of the Wars* and the *Anecdota* of Procopius, at the time secretary to Belisarius.[20] He was living in Constantinople during the first outbreak in that city. There is no doubt about his

talents as a clinical observer. His account, moreover, demonstrates that plague cannot have changed very much over the centuries. The sudden onset, the coma or the delirium which rapidly sets in, the characteristic black rash of the septicaemic form of the disease, with its sentence of swift and inevitable death, the presence of buboes in the groin, the armpit or behind the ears, the fact that they were extremely painful and that if they suppurated, the patient generally recovered, were all observed and recorded by him. It is also of interest that although he mentions vomiting of blood, he does not describe the pneumonic form of the disease, a complication which was all too common eight centuries later during the Black Death.

Of great interest, too, are his epidemiological observations. He mentions that "it left neither island nor cave nor mountain range which had human inhabitants", indicating that in course of time it must have saturated the whole Mediterranean basin as thoroughly as did the Black Death in the fourteenth century. He also observed (as indeed did Evagrius as well) a fact common to all epidemics of plague, that it entered a new country usually by way of a port. This we now know to be due to the fact that the disease can be conveyed long distances by the rats which usually infest ships, particularly those which carry grain. He also observed that one attack might confer immunity, so that if the disease returned to an area in which it had been rampant some time before, those who had recovered from an attack in the previous visitation usually escaped, whereas the rest of the population were highly susceptible.

The pestilence first entered recorded history in A.D. 540 in the serrated landscape of Ethiopia, during the reign of Justinian. Thence it travelled down the valley of the Nile

to Pelusium, and then both east and west. In the same year it came to Antioch and added still another to this city's long list of misfortunes, which, since the turn of the century, had included a tremendous earthquake followed by a fire in A.D. 526, another earthquake in 528, and capture in 538 by Chosroes, the Persian monarch.

Little is known of the progress of the epidemic in the lands to the east, other than that it reached Persia. Whether it got as far as China is not known, nor is it known whether it reached India, although there is a reference in the Hindu mythology of the period to a disease of rats which closely resembles plague.

From Pelusium, the infection also travelled westwards over the delta to Alexandria which, although still the repository of the accumulated knowledge of the centuries, was quite unable to halt its progress. Indeed, the great city was well adapted for its further dissemination, since from its harbour departed great fleets of grain ships to feed Europe. It is no matter for surprise, therefore, that it spread to the inhabitants of Constantinople.

With Alexandria, Pelusium, Antioch and Constantinople all infected during the two years between A.D. 540 and 542 it then seems to have taken a leisurely course, although in the end "it embraced the entire world and blighted the lives of all men". It was not until 549 that it reached Arles, 565 that it came to Liguria, 567 Auvergne and Narbonne, 587 Marseilles, 590 Rome and Avignon, and it seems to have ended its peregrinations in Strasbourg in 591. With regard to the rest of the world, the historians are silent; Procopius dismisses it with the simple statement that "it visited all the other barbarians", amongst whom may have been the Irish.

Once it had made its appearance, it seldom disappeared entirely from any one locality. Constantinople, attacked in the year 542, went through another outbreak in 558 which was nearly as severe. Antioch held the record with four visitations at intervals of fifteen years.

Plague victims seldom live very long, and the plague of Justinian was no exception. In Antioch, those who lived longest survived to the fifth day, but in Liguria they lasted only three days. At Clermont "men gave up their souls on the second or third day". To make matters worse, rapid dissolution of this type was by no means confined to the few, and it is on record that about half the population suffered in this way. In Constantinople "at first the deaths were little more than the normal, then the mortality rose still higher and, afterwards, the tale of dead reached five thousand each day, and again it even came to ten thousand and still more than that". Forty years later, Lyons, Bourges, Chalons, Dijon, Arles and Narbonne lost a large part of their population and one Sunday there were no less than three hundred corpses in the church at Clermont. Rome, too, suffered severely, Paul the Deacon summarizing it all with "*Visium oculorum superabant cadavera mortuorum*".[21]

But even epidemics of plague come to an end and the great metal statue on the summit of Castel Saint Angelo in Rome commemorates the procession led by the newly elected Pope Gregory as an act of contrition. It is related that when they were crossing the Aelian Bridge, they saw the Archangel Michael sheathing his sword in token that the plague was over.

What the total death rate may have been is quite unknown but there seems little doubt that it was only equalled in history by the Black Death. Procopius states that several

millions of millions died, but it is doubtful whether the total population was quite so high. Gibbon reduces it to one hundred million, but even this figure is so very much greater than the estimates for the Black Death in the fourteenth century that one has great difficulty in accepting it. Nevertheless, Procopius was quite clear that a combination of starvation, destitution and Justinian himself were responsible for so much human destruction during the sixth century that, with plague as well, the death rate during a period of about fifty years must have been one of the highest in the history of the human race.

For some reason, plague seems to have disappeared in the centuries following that of Justinian. At all events, none of the many epidemics recorded during the seventh to the thirteenth centuries can be certainly identified as being due to plague. But in the fourteenth it came, in no uncertain fashion, in the form of the vast pandemic usually known as the Black Death.[22] It seems to have started in 1345 at Caffa in the Crimea. The city was one of the principal trading posts by which the Genoese and Venetians traded with the Tartars, who, following their violent incursion into Europe under Ghengiz Khan and Batu Khan in the thirteenth century, had now settled down into so peaceful a community that it was possible to travel all the way from the Black Sea or the Mediterranean over the wide spaces of Central Asia to China in reasonable safety and even in some degree of comfort. Merchandise, mostly of the luxury variety such as silk or furs, travelled by this route in fair quantity. Fighting had evidently broken out between the Genoese at Caffa and the Tartars in the neighbourhood of the city, and, for some obscure reason, the city had been under siege by the Tartars for three years. This was bad

enough, but one day during the summer the unfortunate inhabitants became aware that among the objects the Tartars were hurling into the city were a number of corpses. These were no ordinary corpses. They were the earthly remains of Tartars who had died of plague, and the survivors were indulging in a form of bacterial warfare. Despite their promptitude in ejecting the corpses as soon as they landed, the garrison became infected, and De Mussis, a notary of Piacenza, who was among those detained in the city, stated quite simply,[23] "Soon, however, the whole atmosphere was infected and the water poisoned. The foulness increased so much from this putrefaction that scarcely one amongst thousands was able to escape." The outlook was bleak and there seemed little hope for the doomed city. The dismal alternatives of death from plague or a lifetime of slavery on the steppes of Russia must have appeared singularly uninviting. "No-one knew or was at all able to find a way to safety." Then, almost without warning, the besieging Tartars suddenly disappeared.

Without waiting to investigate, the little band of survivors boarded their ships, four being all that were required, and sailed away in haste, leaving the white walls of the town, the silent castle on the cliff, and the hillsides behind, to the Tartars. Their first stop was Constantinople, and then out of the Dardanelles into the Aegean. When it had passed the headlands of Greece, this strange odyssey divided, and "thus it happened that our fleet, manned by a certain number of sailors infected with this poisonous disease, arrived at Genoa, some at Venice, and some in other Christian regions". It is remarkable that they ever reached their destinations for "because this grievous affliction was upon us, of a thousand making the voyage, scarcely ten

survived". It would have been better if they had all perished at sea, for "the sailors, when they reached any land, almost as if evil spirits accompanied them, encompassed their death when they mixed with other men". And "alas, when our ships arrived at our cities we entered our own homes and because of the grievous affliction that was upon us, our relatives and friends hastened from all sides to meet us. But, alas, since we were carrying the shafts of death, when they held us in their embraces and kissed us, from our own mouths, while we uttered words, we could not but pour forth the poison and those returning to their houses soon poisoned their own families."

In this way, the Black Death was brought to Europe. It spread with great rapidity to every part of the continent, all along the north African littoral, and probably by sea to India and China.

It is probable that a high proportion of the deaths was due to the pneumonic form of the disease. Thus Gui de Chauliac, who was in Avignon during the Black Death, mentioned that "the organs of respiration were seized with a putrid inflammation, a violent pain in the chest attacked the patient, blood was expectorated, and the breath suffused a pestiferous odour".[24] Michaelis Platiensis, in Messina, says that "they violently spat forth blood and after spitting for three days incessantly without any cure for the dreaded disease, they departed from life".[25] It is probably for this reason that the death rate was so high.

Altogether, the loss to Europe has been estimated by Hecker at 25,000,000 out of a population of 105,000,000. Krafft-Ebing went so far as to put it at three-fourths of the population. The East fared little better; 23,840,000 are said to have died in the Orient together with 13,000,000

in China. Caramainia and Caesarea were depopulated, Gaza lost 1,000 a day, Hims 300, Alexandria 1,080, and Cairo 10,000 to 15,000 a day, while in the city of Babylon "in less than three months in 1348, 480,000 are said to have perished from the ravages of the disease."[26]

There can be no question that the Black Death was the most nearly successful of all attempts by parasites to wipe out the human race. Contemporary accounts emphasize the utter devastation which followed it, with whole tracts of country completely, or almost completely, denuded of inhabitants, and with no one to till the soil or tend the cattle. But even so, the ultimate effect of the visitation varied considerably in different countries. In some, nothing very permanent resulted, the population was soon made up, and things progressed, or, as occurred in the Tartar and Arab dominions, retrogressed at about the same pace as before. Its most profound and lasting effects seem to have been on the agricultural economy of England, where it sounded the death knell of the feudal system, and converted the villein into the yeoman farmer of our countryside.[27]

Although the Black Death came to an end in 1351, the disease remained in Europe for four hundred years. For a time it would be quiescent, producing little more than a case here and a case there, but at irregular intervals there were great outbursts, which, unlike the Black Death, were usually limited to a single city or province. London certainly had fairly severe epidemics in 1368, 1375, 1390–91 (this being compared to the Black Death for severity), 1433, 1449–50, 1464, 1466–67, 1478–79, 1500, 1513, 1529, 1532, 1535, 1563, 1592, 1603, 1625, 1635 and 1665.[28] For over three centuries, therefore, few Londoners managed to escape fairly close acquaintance with the disease in

severe form on at least two occasions during their lifetime.

The cities of the continent were little better, particularly Venice, for through her port passed most of the commerce with the East, and while she acquired great wealth from the silks and spices she brought to Europe, she also quite frequently imported plague as well. There were severe outbreaks in 1410, 1423, 1465 and 1512 (in which Giorgione died, infected, so it is said, by his mistress). One of the worst seems to have been an appalling outbreak in 1575, lasting for three years; in this Titian died, together with about 50,000 others—a quarter of the population of the city. Another epidemic in 1630–31 caused the death of 46,490 persons, and left as a legacy the splendid Santa Maria della Salute as a thank offering for its cessation.[20]

The other cities of Italy were infected nearly as badly. Rome, for instance, had twelve severe outbreaks in the sixteenth century. Milan lost 150,000 persons in 1630 in an outbreak which led to the canonization of Carlo Borromeo who was its Bishop at the time. Vienna, too, in close contact with the Turks, went through a severe outbreak in 1679, which is commemorated by the piled baroque and highly irrelevant allegory of the Pestsäule in the Graben. Another came in 1713, whose 120,000 dead are remembered in Fischer von Erlach's Karlskirche. A few years later, in 1720, came the great plague of Marseilles which spread to Provence and killed 87,659 out of a population of 247,899. Thereafter, the disease slowly retreated eastwards, but it showed something of its old form with 80,000 deaths in Moscow in 1771.

This was its last major appearance in Europe, but for a time it persisted in the Balkans, Syria, Asia Minor, the

Caucasus, Armenia, Mesopotamia, Persia, parts of India—particularly the Kumaon and Gharwal—and in the mountain fastnesses of Yunnan. Sometimes it practically disappeared, only to reappear again, but these outbreaks were never of more than local importance.

But in 1894 it awakened from its torpor and attacked Kuantung and Canton in southern China and then spread to Hong Kong, at that time the second largest port in the world. Here it commanded the sea ways of the world.[30] By 1896, it had reached Bombay, and in 1903 there were a million cases in India alone. It also went north to Manchuria and in 1910–11 there were 60,000 deaths in the tarbagan country outside Mukden. It reappeared in 1920–21, when there were 8,503 deaths.[31] Other countries too received it: Japan, the Philippines, Australia, Hawaii, North America, and North Africa. Even England had a few cases. Except in China and India, the disease was soon brought under control, but its importation has resulted in several species of rodents in some of these countries becoming infected. In consequence, the ground squirrels not only of California but in time those of many others of the western states of America became and have remained infected. So too are some of the rodents of Africa and the tarbagans of Manchuria. In all these places, cases occasionally occur amongst farmers and others who come into contact with these animals. But there has been no major outbreak. Nevertheless, the threat remains, and we must never forget it.

Typhus

Typhus is not an easy disease to diagnose, and for this reason its part in history is too often obscure, but there is no doubt that because it is transmitted in its most severe

form by lice, it is usually during times of war or civil strife that it is at its worst. Unlike most of the great pestilences, it seldom appears in time of peace and plenty.

So far as we know, its first appearance was the Plague of Athens, well known from the account of Thucydides. There is, it must be admitted, doubt whether this disease was in fact typhus, but the balance of evidence would suggest that it was. But there can be no doubt that it was a serious complication at a difficult period in the history of the city; how much it contributed to the eventual downfall of Athens will never be known.

If the disease afflicted the Romans, we are quite ignorant of it. Whatever their faults, their love of bathing probably saved them from the undue attention of such insects as *Pediculus corporis*, and this factor alone may have prevented typhus. Because of the difficulties involved in diagnosis, it is also impossible to say whether any of the numerous epidemics which afflicted Europe during the Dark and Middle Ages were due to typhus; but considering that after the eclipse of the Roman Empire, bathing had become almost a rarity, and body lice must have become correspondingly commoner, there is every reason to suppose that it did occur quite often.

In 1528, typhus definitely stepped into history again when it played a decisive part in the long struggle between the France of Francis I and the Holy Roman Empire of Charles V. In the spring of that year, a French army of 30,000 besieging Naples was attacked by typhus. Within seven weeks "a mere handful remained, consisting of a few thousands of cadaverous figures, who were almost incapable of bearing arms or of following the commands of their leaders".[32] The siege of the city was forthwith raised

and the remnants of the besieging army fled, to the accompaniment of thunder and heavy rain. Italy was lost to the French and Francis and Charles settled down on somewhat more equal terms to their almost endless bickering, until the former's death in 1547.

That fearful visitation known as the Thirty Years War provided a battlefield which was highly favourable for the operations of the disease. Typhus was therefore rife from 1618 to about 1630. Although the disease did not disappear, it was largely supplanted by plague in the second half of the period of hostilities, that is, from 1630 to 1648.[33] In consequence of these two diseases, together with typhoid, dysentery, emigration, and starvation, the population of the affected areas fell precipitously from 16,000,000 to 6,000,000 of which only about 350,000 died in the so to speak legitimate slaughter of warfare. This epidemic had far-reaching effects: indeed, Aldous Huxley has suggested that Europe is still suffering from them. It may have been responsible for the dissemination of typhus in Eastern Europe, and its introduction as an endemic disease. When Napoleon mustered his forces in 1812 for the invasion of Russia, it is probable that they picked up the infection, for there seems little doubt that, during the later stages of the retreat, when the Grande Armée had become very dirty and very lousy, the disease played havoc amongst the survivors and together with typhoid, dysentery and mere starvation, was responsible for the catastrophe which overtook them.

Typhus is the one disease which makes Ireland of interest to the epidemiologists. It has been present there for centuries as an endemic disease. It was certainly common as early as 1652, and never entirely disappeared. In times of stress, such as a failure of the harvest, it almost invariably produced

an epidemic. In the nineteenth century, there were six such outbreaks: in 1816–19 (when with relapsing fever there were 700,000 cases out of a population of 6,000,000), 1821–22, 1826–28, 1836–37, 1846–47 and again in 1862–64.

That of 1846–47 was by far the worst, and was one of the consequences of the great Irish famine, when for two years the potato harvest on which most of the peasantry depended for their food supply failed almost completely because of an attack of potato blight brought on by the wet and stormy weather. Typhus need not have appeared—for starvation alone does not cause it—had it not been for the prevailing economic theories that any form of dole or out-relief was inadvisable and that in case of destitution, entry into the workhouse was the only alternative to death from starvation. These places of refuge became seriously overcrowded with unwashed wretches, and the lice they brought with them sufficed to transmit the disease. Together with relapsing fever, it soon spread to the population outside and to the prisons as well. Dysentery too made its appearance because the sanitation of the workhouses was not above suspicion.[34]

The epidemic lasted from the latter half of 1845 to 1850 and during this period no less than 190,298 died of typhus, 105,613 of dysentery and cholera, and 17,494 of actual starvation. In addition to these deaths, the country also lost about a million persons who emigrated, mostly to England or America.

This in itself was bad enough, but Irish susceptibilities had been deeply wounded by the provision of soup kitchens for feeding the starving multitudes, and by the institution of large schemes of public works in which an army of 12,000 officials superintended 734,000 Irishmen earning their daily bread by attempting to drain the bottomless bogs of their

native country, building bridges over nothing in particular, or roads which seldom led anywhere. Mass evictions by absentee landlords and large scale emigration heaped the cup of humiliation to the full. There can be little doubt that typhus had much to do with the anglophobia which still affects many of the citizens of the U.S.A.

Typhus also played a prominent part in Serbia soon after the outbreak of the war in 1914. The disease broke out in the Serbian army in November of that year. A quarter of the army was lost and half the Austrian prisoners. At the same time, a major part of the population was in full flight southwards, overcrowding the billets and villages on the way with a lousy, unwashed multitude. At least 200,000 of the population died of it. Almost all the 400 doctors in the country caught the disease and 126 died. But when the spring came to bring out the white opium poppies beside the Varder, the worst was over and with the heat of June there was no more typhus.[35]

This, however, was merely the overture to something far worse, for the Bolshevik revolution in Russia in 1917, and the blockade and civil war during the subsequent years, caused an almost complete breakdown in the internal economy of the country.[36] It was not long before the disease made its appearance. "In 1918–19 it was principally the *Mechotniki* (sack carriers), who, coming from the larger cities where terrible conditions prevailed, travelled in search of provisions, chiefly flour, to save their families from starvation, and in the course of their wanderings collected lice and typhus more often than the much sought-after provisions." The epidemic might have localized itself had not the Russian railways, usually looked upon by the West as negligible factors in world transportation, decided to take

a hand in the proceedings. Despite the entire removal of *their* managing directorate and most of the operating engineers, they eventually disseminated the disease over large areas of Russia. In the process, railway travel, never very luxurious, became a matter of extreme peril, and "no person travelling by rail can consider himself free from the danger of infection until two weeks after the journey. Even high officials travelling in special carriages do not always escape infection. For the ordinary traveller who has to use the *teplouchki* (goods trucks with iron stoves which hardly ever act and often exist only in name) infection is almost a certainty."

The prevailing confusion rendered the vital statistics of the nation somewhat inaccurate, and official estimates of the casualties from the disease probably tended to err heavily on the side of conservatism. For this reason, Professor Tarassewitch, who had no love for the new régime but abounding regard for his own people, was forced to employ a species of inspired guesswork to determine the number of cases and the death rate. In 1922, he reported to the League of Nations that in 1918 there had been 700,000 cases; in 1919, 6,600,000; in 1920, 6,500,000; and in 1921, 1,200,000, to which should be added another 9,950,000 for Siberia, the Ukraine and other places for which there were no statistics at all. This made a grand total of 24,950,000 cases in four years. And as the death rate was in the neighbourhood of ten to twelve per cent, it follows that from two and a half to three million Russians died of this one disease in the four years.

Relapsing fever is also transmitted by lice and naturally found the prevailing conditions highly congenial. There were, in consequence, between eight and ten million cases.

Cholera, too, appeared but its effects were by comparison much less serious, 182,722 cases being reported.

When the second world war came, the German drive across Poland and southern Russia, as far as Stalingrad, took them across the endemic areas and there were many cases of the disease. But a liberal provision of delousing stations succeeded in preventing a serious outbreak.

There were other epidemics in the second world war, one of which made history. This was the epidemic in Naples at Christmas, 1943, when following its liberation, the population of the city was living, for the most part, in crowded air-raid shelters with no opportunities for bathing, or obtaining a change of clothing. They had therefore become very lousy and typhus was increasing rapidly. Attempts to delouse them by time-honoured methods might have proved difficult, if not impossible. But the new insecticide, D.D.T., was available and what is more could be applied in powder form, so that the population of Naples had the unique experience of having a white powder blown down its neck, up its sleeves and down its trousers. Despite its simplicity and the speed with which this measure could be carried out, the lice of Naples suffered a sudden demise and typhus died with them. It was the first time in history that an epidemic of typhus had been halted in mid-winter.

We might, therefore, sit back and with some justification congratulate ourselves that future wars, rebellions and famines need not be accompanied by the typhus which almost invariably accompanied them in the past. But the louse may, like many bacteria when faced with extinction by the antibiotics, retaliate by producing races which are resistant to D.D.T. Reports from Korea suggest that this

has already occurred. It is therefore improbable that we have finished with typhus.

Cholera

Unlike most other diseases, cholera would seem to be a comparatively recent arrival on the epidemiological stage. There are no references to any such disease until the sixteenth century, when in 1517, 70 men in a Portuguese ship on its way to China died of a disease called "Pessima Maladia di Flusso". In the subsequent years there are scattered references to diseases called Mordexin, Mordechin, or Mort de Chien, all occurring in India, Ceylon or the East Indies, some of which were almost certainly cholera. In these outbreaks, comparatively few persons were infected and the area involved was also very small. But in 1781 something more violent was reported from Bengal, where 4,000 persons were said to have died.[37]

The real importance of cholera, however, was not apparent until so recent a date as 1817 when, in the August of that year, without warning, it struck the unfortunate inhabitants of Jessore. Situated in the delta of the Ganges, this seems to have been a very crowded and dirty city surrounded by marshes and impenetrable jungle, and well fitted to be the birthplace of what was to become one of the major plagues of Mankind. In a short time, about 10,000 of the inhabitants died. It was not long before the disease had travelled the sixty miles to Calcutta, where the drains are even now not above suspicion, and in the course of time it reached the army of the Marquess of Hastings, at that time engaged in eliminating the Pundharees. Despite the fact that he lost 9,000 men from the disease, the campaign was successful, the territories of the East India Company

were considerably extended, and peace came to a land which for many years had known nothing but war. The Marquess was able to sit back, and, as seems to be the fate of all the more successful viceroys of India, await the inevitable attacks of lesser men which would ultimately lead to his resignation.

With so auspicious a start, the disease was not content to remain in India and traversed most of Africa and large parts of Asia. This took six years and by the end of 1823 the disease had disappeared.[38] In 1826 there was a reawakening, and in 1827 it once again left India and travelled as far afield as Britain in the north, the United States and Canada in the west, and Japan in the east. This wave was over by 1837, and outside Asia the disease again disappeared completely. In 1840, however, it was once more widely prevalent in India, and gradually invaded the Philippines, China and Afghanistan in 1842. By 1844 it had reached Persia and Bokhara, in southern Russia. From these centres it gradually crept outwards to circumnavigate the globe, exasperating Palmerston to a homily on the virtues of sanitation in place of prayer, as a prophylactic measure, and, perhaps most important of all, providing a certain Florence Nightingale with a sufficiency of patients in the Crimea to found a whole dynasty of Ladies with Lamps. This wave was over by 1863. The fourth pandemic also started in the basin of the Ganges, during 1865, with the disease spreading eastwards to the East Indies, China and Japan, and westwards to Arabia and Somaliland. It infected the pilgrims to Mecca, who eventually disseminated the infection to all parts of the world. This seems to have been its worst explosion, and it cost Europe alone no less than 1,177,455 lives. By 1875 it had gone.[39] Thereafter, its

progress was considerably impeded by the development of water filtration plants and sewage disposal systems, for by now it was fighting a losing battle once it left the customary insalubriety of India. But it still had its moments, and even so recently as 1892 Hamburg learned that it was unsafe to drink unfiltered water straight from the river Elbe. Except for an outbreak in St. Petersburg in 1908–09 and another in Poland in 1905, this was its last success in Europe in full possession of its faculties, although it re-appeared in the Russia which was suffering from the dementia of its revolution. But it has remained a persistent menace to the East, and India had 337,000 deaths in 1930 and 216,580 cases in 1944. There is also another focus of the disease in the Near East so that unless extreme watchfulness is maintained and anarchy avoided, cholera may, from the strategic ports of Suez and Port Said, once again invade the seaways of the world.

Dysentery

Dysentery is a disease of varying degrees of severity, several different parasites producing essentially the same symptoms. One variety is caused by a protozoon, *Entamoeba histolytica*; this tends to be chronic and because it may produce an abscess of the liver, can be a very disabling disease. But, on the whole, the most important type of dysentery is that which is produced by bacilli closely related to the *Bact. coli*, a normal inhabitant of the intestines. There are several different varieties of dysentery bacilli. One, named after the Japanese bacteriologist Shiga, produces a very severe form of the disease with a high death rate. Another which commemorates Simon Flexner, at one time head of the great Rockefeller Institute in New York, is

rather more gentle. But there are many other varieties as well.

The organisms which produce the disease are world wide in distribution. Where sanitation is good, they do very little harm. But where it is not, and particularly if the climate be hot and with abundance of flies, it produces a steady and unrelenting series of infections. Under such conditions a high proportion of the inhabitants become carriers. Children born into the community become infected sooner or later and in their turn become carriers. In this way the seeds of the disease may be perpetuated more or less indefinitely. Because of this, dysentery is an endemic infection in many parts of the Mediterranean basin, and the southern part of the Asian mainland. But it has no objection to a temperate climate, and when suitable opportunities offer, it generally makes its appearance.

In civilian populations, the disease tends to persist merely as a grumbling endemic infection. But it steps into the drama of the epidemic when large numbers of uninfected and therefore susceptible individuals are transported into an area in which it is prevalent. Because such individuals are usually soldiers, engaged on their lawful occasions of invasion, occupation, or, as seems to be fashionable nowadays, liberation, it follows that dysentery loves the soldier. For the hygiene of armies has usually been poor, or totally lacking, and this has invariably given the disease its opportunity. Very soon, usually long before hostilities have begun, a large proportion of the troops have caught the disease. The death rate depends on the particular variety of organism involved, but it is usually high. Even if those infected do not die, they take a long time to recover. In consequence, dysentery has probably decided more campaigns than any

other factor. It has certainly killed far more soldiers than any weapon. And it has undoubtedly altered the course of history on many occasions.

The first Persian invasion of Europe under Darius was probably checked by this disease as much as any other factor. It probably played an important part in the retreat of Xerxes from the third invasion of Greece in 400 B.C., when, after Salamis, the miserable remnant of the 500,000 who set out were finally ferried across the Hellespont in boats.

Dysentery, too, played a prominent part in the Crusades, particularly the Second Crusade. It went with the Black Prince to Spain, and was prominent in all the wars of the Middle Ages. Albrecht of Germany, along with most of his host, was destroyed by it when, already at Baghdad, he was about to emulate Alexander the Great.

The same disease had much to do with the failure of Charles V at the siege of Metz, and of Frederick the Great to hold Bohemia after he had beaten Maria Theresa. But perhaps its most decisive entry into warfare came in 1792 when Frederick II of Prussia, representing the vested interests of most of Europe, was on the point of entering France in order to deal suitably and decisively with the dangerous new ideas embodied in the young French Revolution. Losing 12,000 men out of 42,000 from dysentery, he evidently concluded that the bacteria of eastern France were more malicious than the doctrines of Paris, and beat a hasty retreat across the Rhine, leaving the revolution to take care of itself.

Having saved the Revolution for Napoleon, the disease showed its impartiality by assisting in his downfall. For the Grande Armée was heavily infected by it before it ever reached Russian territory. It also accompanied the British

to the Crimea. Indeed, considering the ineptitude of the medical department of the Army at that time, it would be very surprising if it had not. Even in the newer and cleaner environment of the New World, it also plagued military operations. In the American Civil War, no less than 30 per cent of all the deaths in the Federal troops were due to this one disease. And even so recently as 1915, it made Gallipoli very nearly untenable to the British Expeditionary Force.

Although dysentery is primarily a danger to the soldier, civilian populations may suffer in the same sudden and dramatic fashion, if circumstances alter in such a way as to permit of the passage of the organisms to large numbers of susceptible persons. Epidemics are therefore not unknown in asylums or in concentration camps and prisons, if there be overcrowding and inadequate sanitation. Probably for this reason, dysentery was widely prevalent in Ireland during the famine years of 1845–47. It is also common in times of invasion when hordes of refugees are herded together in insanitary surroundings.

In all such instances, the epidemics are generally localized, and although severe, do not travel very far. In this respect the disease seldom learns much about geography in the way plague or cholera have done in the past. But during the middle years of the third century A.D. there occurred a widespread epidemic or series of epidemics which is frequently called the Cyprian Pestilence. Unfortunately we know very little about this outbreak, and the only account we possess of its symptomatology comes from a sermon preached by St. Cyprian and quoted in the appropriately named *De Mortalitate* as follows:[40]

"There is this difference between us and they who know not God; that they complain and murmur in their adversity

whereas adversity does not turn us aside from the truth of virtue and faith, but rather strengthens us in suffering. The fact that although the belly drains away the bodily strength in a diarrhoea, that the fire conceived in the internal organs, injures the fauces, that the ceaseless vomiting disquiets the intestines, that the eyes burn with blood, that the feet or other parts of their limbs are cut off by a contagion of morbid gangrene, that as a result of falls and bodily injuries a weakness or paralysis comes upon them, or their hearing is impaired or their vision is dimmed, all these serve as teachings for our faith."

Ecclesiastics in the pulpit seldom give technical details with the precision of a lecturer, and in any event Cyprian was an amateur. But this information is all that is available, and although many different diseases might produce a clinical syndrome of this description, it is possible that St. Cyprian was referring to dysentery.

Little is known of the extent of the disease beyond the fact that it first appeared in A.D. 250 in the valley of the Nile, and that it was at Neo Caesarea in 256, in Rome and Greece in 262, where 5,000 deaths a day were reported, and in the Balkans in 269. It is not even certain whether the same disease was responsible for these different outbreaks, and anyway, the years between 251 when Decius died and the death of Claudius Gothicus in 270 were some of the worst suffered by the Roman Empire. It was under assault from all quarters of the compass by barbarian tribes and so great was the disorganization that it would have been surprising had epidemic disease not made its appearance. The prevailing note was extreme hopelessness: Eusebius, speaking of Alexandria, echoed the prevailing pessimism. "Bloody civil war strewed the streets with corpses and the

Nile was stained with the blood of the slain. From the earth, the lakes and the streams emanated vapours as if a putrid air had been settling down from all the dead heaped in the squares. And then one wonders whence (and has no answer) all these continual epidemics come from, wherefore all this decay and manifold and frequent destruction of human life."[41] Things seem to have been little better in Italy where Heironymus, with possibly some exaggeration, stated quite specifically that the human race had been all but destroyed and that the earth was returning to desert and forest.[42] There was certainly wide depopulation over large areas of central Italy, with the few survivors sheltering in the cities. Only the farms in their near neighbourhood remained under cultivation, the more distant farmlands being overgrown and only suitable for hunting. What had been prosperous agricultural country on the coasts of Etruria and Latium reverted to swamp, with malaria as a further hazard for the remaining inhabitants.

What part the epidemic played in the events of those twenty years can only be guessed. But when it was all over, the Roman Empire was but a minuscule of its former self, with Spain and Gaul lost, the Goths in possession of Dacia and the Balkan peninsula, and Syria in the hands of the Persians. If smallpox started the process of decay during the second century A.D., it is equally possible that dysentery may have materially hastened the process in the third, while plague in the sixth may have administered the *coup de grâce*.

Influenza

Influenza is generally a mild disease coming about every two years or so. As such it merits little notice, but occasionally, more severe forms of the disease make their appearance.

Two *seiches* or waves of exalted virulence have occurred within living memory. The first,[43] in 1889, seems to have come upon the world from areas of extreme inaccessibility. There was severe influenza in Athabasca in northern Canada, and also in Greenland, in May and June of that year. But the main focus seems to have been the flat-roofed hovels and narrow streets of the city of Bokhara in Russian Turkestan. The resurgence of the disease may have been connected with the smells which even connoisseurs of the odours of the East described as unusual. But it might have stayed there and failed to cross the wide spaces of the Kizyl Kum and Kara Kum deserts had not the Russians recently suffered from an attack of empire building. In this process they had constructed a railway—mostly of left-over rails—from the Caspian over the deserts to Bokhara and Samarcand, not only to facilitate the export of carpets from the two cities, and so place on the world markets the genuine version of an article which Manchester was beginning to manufacture, but also (according to the fertile imaginations of the India office) as a spear-head for the conquest of India.

The railway was duly opened, and carried as one of its first passengers George Nathanial Curzon, conscientiously acquiring the local knowledge to fit him in later life for the drawing of lines across maps which have since rendered his name anathema to the inhabitants of both Poland and Russia. It is doubtful whether the resultant export of the genuine Bokhara rugs caused much perturbation to the carpet manufacturers of England, but the railway took a prominent part in the export of influenza. The disease broke out in May, infecting more than two-thirds of the inhabitants of Bokhara, and killing a high proportion of them. Then,

realizing the potentialities of world communications, it spread along the thin, tenuous line of steel to the west. Even so, its progress was leisurely and it was not until October that it reached St. Petersburg. Thereafter, it had the facilities of better managed transportation at its command, and by the aid of Wagons-Lits and the Hamburg-America line, the rest of the world was infected with great rapidity.

The world was thereafter free of visitations of this sort for many years, but in 1918, when the last German onslaught in the west had been held and the world was beginning to hope that the war might soon be over, the summer, which had already been far too full of incident, was further enlivened by the sudden appearance of a disease which incapacitated large numbers of soldiers and civilians without going so far as to kill many of them. This was a very mild type of influenza and died away in a very short time. But as the old Somme battlefields were being crossed once again and the Hindenburg line loomed through the mists of early autumn, something infinitely more sinister made its appearance. This was also influenza, but of more lethal variety. It appeared more or less simultaneously in different parts of the world.[44] It was present in Chungking in July, in Meshed in Persia in early August, in the port of Brest about half way through the same month, and in Sierra Leone at the end of August. From these centres it spread to most of the world with a rapidity far greater than any forest fire, and in consequence the death rates in places so far distant as London, Berlin and Bombay rose and fell with singular unanimity. Australia, remote in the southern seas, was able to avert the peril for a time; she imposed a rigid quarantine, but the disease broke through and by February, 1919, was

no better off than the rest of the world had been three months earlier. Tasmania also succeeded in keeping it at bay, and a little more successfully, but in August, 1919, it too was afflicted.

From the first, it was apparent that the disease was much more uncharitable than the influenzas of any previous years. It was the exception to escape the disease and whole populations went down with it at once. In some schools, nine out of ten pupils had to retire to their beds at the same time, and for a short period it would have been impossible for the British Navy to put to sea. In addition to this high incidence, the patients showed lamentable tendencies to be afflicted with a particularly unpleasant form of pneumonia with, in many cases, infection by streptococci.

The chances of survival depended to a large extent on the skill of the nurses, and for this reason the death rate varied considerably in different parts of the world. The Western world got off comparatively lightly. In America, for instance, 2·4 per 1,000 of the population of the State of New York and 3·7 of the province of Ontario died. But in Mexico the death rate was 23·0. In England the rate varied with the locality. In the smoke of West Bromwich it was 17·9, but in the gentler climate of Bournemouth it was only 5·1. Even in London one's place of residence might mean the difference between life and death, for 15·1 per 1,000 were taken from the little houses in the huddled streets of Battersea, whereas only 7·9 died of those who lived in the tall mansions of Kensington.

In Asia it was far worse. Little is known of China, but in India it has been estimated that 40 per 1,000 died. In Samoa it was 250 and in Fiji 56 per 1,000.

There is no doubt that the total number of deaths in the

world was not far short of one per cent of its population. Naturally, the figures on which this calculation is based can be little more than estimates; but Dr. Jordan considers that 1,000,000 in North America, 327,250 in South America, 2,000,000 in Europe, nearly 1,000,000 in Australasia, 1,250,000 in Africa, and the colossal figure of 15,750,000 in Asia, a total of over 21,000,000 persons, probably died from influenza in about twelve months. Although this number is of much the same order as the death roll from plague in the Black Death, the population at risk was very much greater.

Nevertheless, it had few, if any, effects on the affairs of nations despite its occurrence in the closing phases of what was, at that time, the most destructive war in history. Beyond an outbreak of Ministries of Health in many parts of the world, there is little else to record. There was certainly no contemporary literary outburst, no Homer with his tremendous lines,

> "Nine days the heavenly Archer on the troops
> Hurled his dread shafts",

no Tasso to write, as he did of the Christian army before Jerusalem,

> "And in each vein, a smouldering fire there dwelt,
> Which dried their flesh and solid bones did melt",

there was no Decameron of Boccaccio, no Machiavelli, no Benvenuto Cellini, no Daniel Defoe. Nor was Kipling who had appreciated the metrical possibilities of cholera, inspired by the greater catastrophe of influenza. The sole poetic reminder is a short stanza from a resident on the Gold Coast:

"The fell disease on every side
Stalks forth with tainted breath,
And pestilence with rapid stride
Bestrews the land with death."[46]

This very brief survey of epidemic disease shows what horrors some of our ancestors had to face. When one considers that from fifty to seventy per cent of all the deaths in what might be described as normal times over many centuries were probably due to parasites, the additional slaughter brought about by the occasional appearance of a severe epidemic of plague, typhus or dysentery, indicates how extremely important parasites eventually became in the struggle of the human race to survive and rule the earth.

Nor, for that matter, is Man necessarily alone in this. Very little is actually known of the struggles of wild animals to survive, of how many die of starvation, how many from accidents or from epidemic diseases of their own. But there seems little doubt that when the population of any species becomes too large for the available food supply, epidemic disease may take a hand in the proceedings and correct the balance, by killing a large proportion of the population.[46]

For this reason, we may perhaps view parasites with a little more charity than one might be tempted to do. It was chiefly by means of their activities, particularly in their predilection for encompassing the death of the young of the human species, that they have prevented the too rapid multiplication of the human race. This may appear cruel and inhuman, but it is a fact.

CHAPTER FOUR

MIASMAS OR MICROBES

> The fourth sort of little animals which drifted among the three sorts aforesaid, were incredibly small; nay, so small, in my sight, that I judged that even if 100 of these very small animals lay stretched out one against another, they could not reach to the length of a grain of coarse sand.
>
> ANTONY VAN LEEUWENHOEK, September 7, 1674.

ALTHOUGH PARASITES LEVIED a fearful toll on the human race for many centuries, Man, being distinguished from the brute creation by his capacity for constructive thinking, cannot have been indifferent to the illness and death which so frequently came to him and his family. He must have made some attempt to prevent them, and to cure the illnesses after they had developed. In order to do this with any hope of success, he would first have to evolve a theory as to why they occurred at all. Obviously, the nearer the theory approached the truth, the more successful would his prophylactic and curative measures become. There is no doubt that in the course of the ages, a great many theories have been evolved to explain illness and death, and it would be a formidable and, on the whole, a fruitless task to review them all. But most of them can be placed into one or other of three categories. The first and by far the oldest is what might be called the religious theory of disease, which postulates that it is due to the machinations of devils, the displeasure of the Deity, or to some malign

influence exerted by the stars and planets. The second, which we shall call the Greek theory (although it may be far older), was evolved in the Mediterranean when civilization was young, and dominated medical thinking for at least 2,000 years. The third is the modern theory that disease is due to disturbances in the function of different organs and tissues, owing to the presence of parasites, the uncontrolled overgrowth of certain cells (to cause cancer), the degeneration of important tissues such as those of the heart or brain, disturbances in the activity of the endocrine system, and alterations in the metabolism brought about by lack of certain substances in the diet.

It is highly probable that Palæolithic and Neolithic Man subscribed to the religious theory of disease and employed medicine men or ministers of religion to do their doctoring for them. His descendants in many parts of the world still continue to do so. Treatment would therefore consist, for the most part, of measures designed to rid the victim of his devil, to placate the Deity, or to circumvent the particular heavenly body exerting its baneful influence on the mortals below. While treatment along these lines may undoubtedly be of value in certain functional and mental disorders, it is improbable that it ever had much effect on parasitic infections. We may therefore leave this and pass at once to the Greek hypothesis.

Despite its antiquity, this is of considerable importance for there is no doubt that many of the amenities we enjoy nowadays in our cities stem directly from its application during the nineteenth century.[1]

This theory of disease was probably formulated by Empedocles, who laid it down that so long as the four humours, blood, phlegm, yellow bile and black bile were

at peace with one another, the individual was in perfect health, but that if one and still more if two, became preponderant and upset the balance, the individual became ill. The stimulus most likely to effect this came from the environment, because the four humours were attuned in some way to the four elements, air, fire, earth and water, of which the globe is constituted. Each of these four elements could have different amounts of the four qualities, heat, cold, wetness and dryness, and it was the variations in these qualities of the four elements which operated on the four humours of the individual, in such a way as to produce disease.

For these reasons, the particular qualities of the atmosphere in the neighbourhood of the patient, and in particular, its temperature and its humidity, the variations in the same qualities of the earth beneath him and of any water which happened to be in his vicinity, could by themselves determine how much and what kind of disease he was likely to suffer from.

Ingenious as this theory was, it might not have lasted very long had it not been for the deductions of one of the greatest men of all time, Hippocrates. These were founded on observation of the diseases prevalent in the Island of Thasos, the great majority of which were obviously parasitic in origin. Other forms of pathological upset might and did occur, and the theory as to their causation was precisely similar, but the fact remains that the observations made by Hippocrates and the conclusions reached by him mostly concern diseases that we now know to have been due to parasites.

One of the principal conclusions he reached was that there was a very definite connection between locality, the physique of the inhabitants, and the type of infection they

were likely to suffer. Thus, the unfortunate inhabitants of a district afflicted by hot winds were, according to Hippocrates, distinctly mediocre, for the "heads of the inhabitants are of a humid and pituitous constitution and their bellies subject to frequent disorders owing to the phlegm running down from the head". Those living in cities exposed to cold winds would seem to have been better specimens for "the men must necessarily be well braced and slender, and they must have the discharges downward of the alimentary canal hard and of difficult evacuation, while those upward are more fluid and rather bilious than pituitous. Their heads are sound and hard".[2]

He also noted that there was a connection between locality and the type of disease likely to be encountered. There was a very definite and clear-cut tendency for certain infections to occur in certain localities. But he went even further and showed that the infections occurring in any one place might vary in character with the seasons of the year, so that in the spring and again in the autumn, when the weather tended to be cold and wet, catarrhs, pneumonias and bronchitis tended to be prevalent, whereas during seasons of heat and moisture, such as occur in summer, respiratory infections disappeared, but instead the "large stiff spleens" of malaria became common. He also noticed that a rainy spring tended to be followed by fever and dysenteries.

In addition to this more or less orderly sequence of endemic infections, as they were called, outbreaks also occurred which bore little relationship to any particular place or time, and for these he used the term epidemics, implying that they were abnormal and unpredictable occurrences.

Nevertheless, it was observed that at all times and particularly during an epidemic, all men were not alike. Some did not catch the prevailing diseases; they were considered to be what we should now call immune; their humours were so well balanced that even a severe epidemic could not affect them. At the other end of the scale were those who drank too much, who were already sick of another disease, the emaciated and the undernourished, whose humours were already out of balance, and who, it was observed, generally took the prevailing infection more rapidly and succumbed more easily than the rest of the population.

In assessing the healthiness or otherwise of any particular region, therefore, Hippocrates was disposed to lay great stress on its climate, the amount of sunshine it received, the direction of the prevailing winds, and such factors as the race to which the inhabitants belonged, their habits, their clothing and the type of house they lived in. All these factors were considered to play a part in predisposing the individual to certain types of disease. But perhaps his most interesting observations concerned the water supply. Not only did he observe the fact that the consumption of water issuing from rocky strata or derived from melted snow or ice might be followed by bad effects, but he also observed that residence in the neighbourhood of marshes and stagnant water was likely to be accompanied by fevers, diarrhoeas and dysenteries.

In epidemics, however, the air was considered to be of prime importance because it was the one thing which came into contact with all men alike and at the same time.

Thus, disease in general, both parasitic and non-parasitic, was thought by the Greeks to be due to miasmas, emanations

and similar influences coming from the earth, the water, or the atmosphere in the neighbourhood of the patient. It was not thought to be due—and this omission is dealt with in more detail below—to parasites or anything resembling them, still less to parasites which might have come from other persons in the neighbourhood of the patient.

In several instances, the Greek theory was partly right, but in a great many more it was completely wrong. It was undoubtedly correct in its conception that the state of health of the individual, and possibly even his heredity or diathesis, might play a part in predisposing him to disease. Nevertheless, this does not always apply, particularly in epidemics, because it is by no means unusual for a healthy athlete to be taken when poor specimens of humanity, whose humours would appear to be completely out of symmetry, are spared. The theory therefore did not always fit the facts.

But it was in the connection between disease and the environment that the theory assumed such great importance. In this respect, it may appear to be perfectly correct on many occasions.

Typhoid, cholera and dysentery may come directly from bacteria present in the water consumed by the patient. The Greek physician, who could not see or cultivate the bacteria, was ignorant of this. But what he knew was that certain types of water tended to produce infections of the intestinal tract. The occurrence of quotidian and tertian fevers in the vicinity of marshes at certain seasons of the year could be explained in the same way. For the protozoon of malaria which causes them requires *Anopheles* mosquitoes to transmit them. But these insects do not occur everywhere

or all the time. They need a special sort of water and special degrees of temperature in which to develop, and it is only in such a type of environment that malaria is likely to occur. Here again, the Greek physician was justified in assuming that malaria came from the air over marshes.

A cold environment undoubtedly predisposes to pneumonia, bronchitis and other respiratory infections. But we now know that the only disease actually caused by cold is frostbite. All that cold weather does is to favour the development of the pathogens responsible for these infections. Nevertheless, the theory was near enough to the truth in these particular instances to suggest that water, marshes and cold weather were themselves directly the cause of the illnesses produced in their neighbourhood.

On the other hand, the theory was in large part wrong when it sought to explain the majority of human infections, particularly such diseases as measles, smallpox and wound infections. These, we now know, do not come from the water supply or from marshes, nor are they transmitted by insects. They can be picked up anywhere, in any sort of weather, but only—and this is the important point—if there are other cases or carriers of these infections in the vicinity. In such instances, the theory was undoubtedly very wide of the mark.

But so long as one lived in a world with abundant intestinal and insect-borne infections—as the Mediterranean world persisted in remaining for many centuries—there was sufficient truth in the observations and deductions of Hippocrates to explain the occurrence of a high proportion of the current infections and thus enable his system to stand, in the main, unaltered for many centuries.

The Greek spirit and teaching were largely adopted by

the Romans who went so far as to import Greeks to act as physicians. There were variants from the main Hippocratic hypothesis; there were even rival strongholds; but on the whole, the citadel erected by Hippocrates remained unassailed. It was indeed, reinforced and buttressed by Galen, who was the towering figure of the Roman period. Avicenna, the next great name in medicine, who lived in the tenth century, and Sydenham in the seventeenth, also subscribed to these doctrines with a few alterations and amendments of their own. This hypothesis even persisted until half-way through the nineteenth century, and Edwin Chadwick and John Simon, who between them probably eradicated more disease in this country than any other two persons before or since, were quite vehement in its support. It crossed the Atlantic and Benjamin Rush of Philadelphia and Noah Webster of New Haven in the early years of the same century were equally certain that yellow fever—the disease which was causing most perturbation at the time—was similarly due to atmospheric pollution and telluric emanations. Indeed, it was not until well on in the nineteenth century, when parasites were finally seen and cultivated, that it finally died.

In its purest form, the Hippocratic doctrine did not admit of the possibility that disease might be transmitted from person to person. Disease was a mutual affair between the patient and the air, the earth or the water in his vicinity. Other people played no part in this. There certainly seems to have been no suspicion in the mind of Hippocrates himself that people could transmit infection to one another directly, or that they could contaminate the air, earth or the water in their neighbourhood with something capable of causing disease. This we now know is one of the principal methods

by which parasitic diseases are transmitted, but any suspicion that it might occur seems to have escaped the Greeks.

The world had, indeed, to wait over two thousand years before this possibility was definitely proved, but there seems all along to have been a suspicion, in some parts of the world at least, before and even during the lifetime of Hippocrates, that disease might be transmitted in this way. Phthisis, for instance, had been recognized as a disease which could be transferred only too easily from person to person, as early as thirteen centuries before Christ. The Ordinances of Manu, written about that time, warned the Indian, who was matrimonially inclined, to beware of women with this type of infection, however eligible they otherwise might be.[3]

Ophthalmia, too, the modern pink eye, was recognized to be a transmissible or catching infection in the work known as the "Pseudo-Aristotle" which dates from about the time of Hippocrates. Thucydides, writing about the same time, was also quite certain that the Plague of Athens was catching; he mentions that the unfortunate inhabitants were "dying like sheep if they attended one another". Leprosy too seems to have been recognized as infectious by the Assyro-Babylonians as early as 1,500 B.C., and the Jews undoubtedly subscribed to the same doctrine because the directions for the disposal of the leper in the Mosaic Law admit of no other explanation. In the second century A.D. Archigenes taught this, and Aretaeus of Cappadocia even went so far as to suggest that it was transmitted merely by a glance.

Galen, who lived in the second century A.D., and who undoubtedly exercised immense influence over succeeding centuries, was therefore forced, despite the fact that he was a whole-hearted admirer of Hippocrates, to admit that the Greek theory had not covered all eventualities. He therefore

stated quite definitely that phthisis, ophthalmia, pestilence (meaning probably the smallpox or similar type of infection which caused the Antonine Pestilence) and certain forms of skin disease were transmissible diseases. Cedrennus too had no doubt that the disease responsible for the Cyprian epidemic in the third century A.D. was so readily transmitted from person to person that a mere glance would suffice. Evagrius, one of the historians of the outbreak of bubonic plague in the sixth century, during the reign of Justinian, was convinced that it too was contagious.

The last three observers were amateurs, but Avicenna in the tenth century A.D. was very definitely a professional, who wrote a text book of medicine which was the standard work for many centuries, and while subscribing to most of the Greek doctrines, he recognized the possibility of the direct transmission of disease from person to person. Indeed, a whole section of fourteen lines in the English translation of the Canon is devoted to this. It is worth quoting in full.

229. *Transmission of Disease from Person to Person*

A. *Transmission by infection.*

(i) From one house to an adjoining one. Here belongs lepra, scabies, variola, pestilential fever, septic inflammatory swellings and ulcers;

(ii) from a house in the wind track of another;

(iii) when one person gazes closely at another (e.g. ophthalmia);

(iv) fancy, e.g. when a person's teeth chatter because he thinks of something sour;

(v) such diseases as phthisis, impetigo, leprosy.

B. *Hereditary transmissions.* Vitiligo alba; premature baldness; gout; phthisis; lepra.

C. *Racial transmission.*

D. *Endemic transmission.* The sweating sickness of Anglia; elephantiasis in Alexandria; aurigo in Apulia, endemic goitre, and many the like.[4]

When the Black Death reached Europe in the fourteenth century, official medical opinion tended to incriminate putrefying corpses far away in China, or fogs which were widespread over Europe. But contemporary amateurs and some doctors as well had no doubt whatever that it was a highly transmissible disease. For it required no very remarkable powers of observation to see that the disease itself had reached Europe from the Crimea in four galleys, and that such isolated countries as England and Norway had been free of the disease until, in the case of England, a boat with an infected crew on board had landed at Weymouth, and, in Norway, a boat laden with woollens from London, with the whole of its crew dead of plague, had been driven ashore at Bergen. The Arabian physicians practising in Spain[5] could also quote instances where the disease had been transmitted to isolated places by infected clothing. There seemed, therefore, little doubt that plague at least was a transmissible disease, in which not only human beings but their belongings could carry the infection.

When syphilis came to Europe at the end of the fifteenth century, it was also apparent that here was another transmissible disease because there was little doubt that it was largely as a result of sexual intercourse that it was likely to be acquired.

During the later Middle Ages, therefore, medical teaching was on the whole in favour of the Greek doctrines as an explanation for the occurrence of disease in general, but admitted that certain diseases such as plague, syphilis, ophthalmia, phthisis and leprosy were exceptions.

No theory had, however, been put forward to account for these exceptions and certainly no one knew what was transmitted. But in 1546, Hieronymus Fracastor, who lived most of his life in Verona and had already written a long poem on syphilis, published a small book called *De Contagione*, which reveals him to have been one of the most original thinkers of all time.[6] In this work he recognized that some particulate material for which he used the term "germ" had to pass from patient to patient in order to cause certain types of disease. He recognized three types of contagion or methods by which disease could be transmitted. "The first infects by direct contact only; the second does the same, but in addition leaves fomes, and this contagion may spread by means of that fomes, for instance scabies, phthisis, bald spots, elephantiases and the like. By fomes I mean clothes, wooden objects, and things of that sort, which though not themselves corrupted can, nevertheless, preserve the original germs of the contagion, and infect by means of these: thirdly, there is a kind of contagion which is transmitted not only by direct contact or by fomes as intermediary, but also infects at a distance: for example, pestilent fevers, phthisis, certain kinds of ophthalmia, exanthemata of the kind called variolae and the like."

Almost the only thing Fracastor omits is an exact description of the size, shape and appearance of the germs of disease. He certainly knew that miasmas were not the cause of disease; the agents were definitely particulate for "I say germs, not simple vapours, for as I said above, there is a great difference between germs and vapours". Nor could he provide an explanation for the ultimate source of the germs, and was inclined to think that spontaneous generation was at least a possibility, postulating that they might suddenly

appear in the atmosphere, although water, marshes and similar situations might engender them. In this he was little more advanced than Hippocrates, but he went far beyond the Master in allowing that having once settled down in a member of the human race, the germs can pass to others "without any general disposition of the atmosphere".

Fracastor did not neglect possible variations in the recipients of the germs, but he cut himself off from both Hippocrates and Galen in abandoning the doctrine that ill-balanced humours predispose to infection, for "countless persons who are perfectly healthy and whose humours have suffered no depravity, nevertheless catch that contagion from merely associating with the plague-stricken or from his clothes". Even so, he was unable to provide an explanation for the converse fact that in all epidemics some persons managed to escape infection despite ample opportunity to acquire it.

Fracastor was, undoubtedly, long before his time, and for many years his ideas were forgotten or neglected. But in spite of this, more and more diseases were gradually recognized to be transmissible. Jacme d'Agramont had, for instance, recognized the transmissibility of measles as long ago as 1348, as did Richard Mead in the eighteenth century, but it was Panum who, in 1846, finally settled the matter in the Faeroe Islands.[7] In 1748, Dr. John Fothergill stated quite definitely that acute septic tonsillitis was a catching disease, and about the same time, Sir John Pringle showed unusual prescience as Physician General to the Forces in not only admitting the possibility that dysentery was transmissible but, acting on this idea, going so far as to institute measures designed to prevent its dissemination.[8]

Further progress had, however, to wait some time, in fact until cholera came to Europe in 1831. In this disease the specific organisms are present in enormous numbers in the characteristic rice-water stools. They may therefore reach the food of other persons in the same household as the patient, particularly if their ideas of hygiene are rudimentary. When this occurs, the disease would naturally be looked upon as contagious or transmissible by fairly close contact. But this is somewhat exceptional, and the principal mechanism by which it is transmitted is for the faeces to contaminate a water supply. In this way, the disease can readily be conveyed to others, miles away, who need not have had any contact whatever with the original patient.

When the disease arrived in Sunderland during 1831, its transmission by water had not then been recognized as a possibility. According to the then prevailing theories, disease could only be transmitted by sexual intercourse, fairly close contact such as occurs when a susceptible person enters a house in which there is a smallpox patient, or by way of fomites such as articles of clothing which had been used by a patient. In view of the fact that in cholera the disease is only rarely transmitted in this way, it appeared to contemporary observers that it was not contagious, and in seeking an explanation for its occurrence, the Greek doctrines were once again invoked. For a time, cholera was seriously considered to be due to odours, emanations and miasmas from the earth.

But only for a time, because in the outbreak of 1854, Dr. John Snow started a series of researches which are models of what can be done with no other apparatus than a notebook, a map and the five senses.[9] Assuming that something was present in the stools which could produce the

disease in other people, he proceeded to investigate the probable routes by which it could reach them. After due consideration he came to the conclusion that water was the most likely means of transmission. In seeking proof of this he was favoured by the fact that the mean streets round Lambeth Palace and Southwark Cathedral, on the south bank of the Thames, received two separate supplies of water. One company, the Lambeth Company, served 26,107 houses with water drawn from the Thames at Thames Ditton, where it was reasonably free of human pollution. The other company, the Southwark and Vauxhall Company, supplied 40,046 houses with water derived also from the River Thames, but taken in at Battersea Fields. The water at this point had had ample opportunities for pollution by cholera-infected sewage from neighbouring municipalities and from boats moored in the Thames, with cases of cholera on board.

Snow's researches established the fact that during the first seven weeks of the epidemic this supply was infinitely more perilous, the death rate from cholera being eight to nine times greater in the houses receiving the Southwark and Vauxhall Company's water than amongst those supplied by the Lambeth Company. In some of the streets of Lambeth, both companies operated and here Snow laboriously ascertained the source of each household's supply. "The inquiry was necessarily attended with a good deal of trouble. There were few instances in which I could at once get the information I required. Even when the water rates are paid by the residents they can seldom remember the name of the water company till they have looked for the receipt." In spite of these difficulties, Snow found that of 300 fatal cases, in 286 the house was supplied with the water of the Southwark

and Vauxhall Company, and in only fourteen by its rival.

Not long afterwards occurred the Broad Street outbreak. In a relatively small area of what is now Soho, there had been over 500 deaths from cholera in ten days. Snow ascertained, again by the laborious process of question and answer, that most of these deaths occurred amongst those who consumed the water of a pump in Broad Street, whereas those living in the same neighbourhood but using other water supplies escaped. There were, for instance, only five deaths amongst the 535 inmates of a workhouse in Poland Street which did not use the water, whereas there were many deaths in the houses nearby. A brewery, also in Broad Street, employing 70 men, who evidently preferred the ale to the water of the pump, did not lose one. On the other hand, an unfortunate lady who had resided in the area, but had moved to Hampstead, was so much addicted to the water of this particular pump that she actually went to the trouble and expense of having a large bottle of it taken by cart every day to her new home. She died, as did a niece who was visiting her and who likewise drank the water.

Snow's obvious conclusion was that by some means the water had become contaminated from a leaking cesspool or drain (a matter which was subsequently confirmed by direct inspection), and the Board of Guardians having been persuaded to remove the handle of the pump, the epidemic promptly ceased.

About the same time, Dr. William Budd of Bristol, in a series of researches of equally convincing simplicity, showed conclusively that typhoid could similarly be transported to others at a distance by contamination of a water supply.[10] Thus, telluric emanations and the like were finally shown to be incapable of explaining two more diseases. Another

was added about the same time when Semmelweis in Vienna and O. W. Holmes in America demonstrated that puerperal fever was transmitted from patient to patient by still another mechanism, the fingers of the obstetrician.[11]

While these developments were taking place, study of animal and insect diseases indicated the probable nature of the agents which were transmitted. In 1835, Agostino Bassi of the small town of Lodi in the Piedmont plain, battling with a wide array of handicaps which included poverty, failing eyesight and ill health, showed that a fungus was the cause of a transmissible disease of silkworms known as *mal del segno*. Anthrax in sheep was studied by Pollender of Wipperfurth and the two Frenchmen, Rayer and Davaine, who in 1849 found the rather large bacilli which they named bacteridia in the blood of infected animals. This was confirmed in a series of masterly experiments by Robert Koch, at that time working as a general practitioner in a little town in East Prussia.

Study of human diseases with the aid of the microscope also showed that agents too small to be seen by the naked eye were present in the tissues in some of them. This process seems to have started as early as 1786 when Wichman of Hanover found mites in the lesions of scabies. Some time later Schoenlein found a fungus in favus of the scalp and another fungus was identified in 1846 as the cause of pitariasis versicolor. In 1873 Obermeier had seen the spirochaetes of relapsing fever in the blood of patients. And a year later the bacilli of leprosy were identified in the cells of the lesions by Hansen. The gonococcus was seen by Neisser in 1879, the bacillus of typhoid fever by Eberth and the parasite of malaria by Laveran in 1880, and Ogston, a surgeon of Aberdeen, saw the staphylococcus in 1881.

But mere demonstration of bacteria in a pathological lesion is not sufficient to prove that they are the cause of it and it required the labours of two very great men to provide such proof. The first of them, Pasteur, showed clearly that bacteria could not arise by spontaneous generation as so many of his contemporaries believed, that they possessed certain chemical activities such as the power to ferment sugar solutions with the production of alcohol or vinegar or the destruction of proteins in the putrefaction of meat. But although he prophesied that microbes could produce disease, the proof of this was left to Robert Koch. Translated to a laboratory of his own in Berlin, he not only isolated and cultivated the bacillus of tuberculosis in 1882 but actually produced the disease in animals by the injection of pure cultures of the organism.

This astounding feat—for cultivation of the tubercle bacillus is difficult enough nowadays—marks the real turning point in the relationship of parasites to Man, and before the end of the century the organisms causing glanders, diphtheria, pneumonia, erysipelas, malta fever, cerebro-spinal meningitis, tetanus, plague, botulism, cholera, dysentery and wound infection had all been identified, isolated and proved to be responsible for the diseases with which they were associated.

Once it had become possible to recognize organisms capable of causing disease, it was not long before their usual sources had been ascertained and the routes by which they travel in search of fresh victims mapped out. This last was perhaps the most important information of all, for with this knowledge it became possible to evolve methods for blocking the routes and so to prevent further infections. In many instances, what had previously been mere suspicion

or perhaps more correctly, inspired guesswork proved, in the end, to be correct. In consequence, it was soon shown that gonorrhoea was due to a specific organism transmitted by sexual intercourse; that diphtheria, cerebrospinal fever and tuberculosis were due to the passage of organisms in air currents from throat to throat; that the organisms causing dysentery, cholera and typhoid fever came from the faeces of a patient with the disease and reached the food or water of uninfected persons, to obtain access to their intestinal canal; and that the parasite causing hookworm also leaves patients in their faeces but bores through the skin of the recipient and travels by the blood stream to the lungs, and then down the oesophagus to reach the duodenum, where it attaches itself to the mucous membrane.

Some diseases were found to come from animals. The organisms of bovine tuberculosis, malta fever and, on occasion, that of scarlet fever could infect the udder of ruminants such as the cow or goat and, obtaining access to the milk, produce the disease in human beings. Tetanus and anthrax, too, come from animals, but gain access to soil, dust or hides of animals, and enter the tissues of a new host by way of scratches or wounds.

But it was not until the closing years of the nineteenth century that another and perhaps the most important of these routes was discovered. This is the part played by insects in the transmission of disease. In 1893, Theobald Smith had shown that texas fever, a disease of horses, was transmitted by ticks but it was Bruce who first showed that a human disease might be transmitted in this way, when he found that trypanosomiasis or african sleeping sickness was carried by tsetse flies. It was not long after this that Manson found that filariasis was transmitted by insects, Ross showed

the same to be true of malaria, Reed and his human volunteers of yellow fever, Nicolle of typhus, and an august and largely anonymous body, the Indian Plague Commission, found that this disease was transmitted by fleas.

Since these fundamental discoveries, the organisms causing many other infections have been recognized and studied in great detail. Their routes from donor to recipient have been mapped out and are generally much the same as those outlined above. It was even possible to correct some serious misconceptions. Plague, for instance, was, as we have seen, one of the first diseases to be recognized as contagious. But when the causative organism was discovered, it was soon found that this is only true of the rather rare and unusual form of the disease, pneumonic plague. The commoner form of the disease, bubonic plague, is actually not contagious, but is transmitted from infected rats to human beings by fleas.

Nevertheless, the mode of transmission of some diseases still defeats us. We still do not know how so universal an infection as the common cold is transmitted. Influenza, too, defeats us. Nor do we know very much about the routes followed by the viruses of poliomyelitis or infective jaundice. There are also many unsolved problems in connection with the transmission of disease by insects. Not every *Anopheles* mosquito can carry malaria even when it outwardly resembles species that can do so. Nor is it known why the distribution of scrub typhus, carried by mites, should be so capricious. These and many other similar problems will no doubt be solved in time. But it is astonishing how much we do know, and how much parasitic infection it is now possible to prevent.

CHAPTER FIVE

THE REACTION OF THE COMMUNITY

Evitare la corruzione della città.
Instructions given to Niccolo Venier, Mario Quirini and Niccolo Belegno on March 30, 1348, during the Black Death, by the Great Court of Venice.

ALTHOUGH TWO RIVAL theories explaining the causation of disease in general and of infectious disease in particular, existed side by side for many centuries, both eventually pointed the way to methods which proved successful in preventing a great deal of infectious disease.

Because the Greek theories of disease held the field for well over two thousand years, it is perhaps hardly surprising that during most of that time whatever methods were employed were for the most part founded on these doctrines. One of the main tenets of the theory was the part played by the environment in the production of disease and whether it was because of this or because it was aesthetically advisable, there seems no doubt that a considerable amount of trouble was actually taken by ancient civilizations to provide a reasonably healthy environment for their citizens. In the process, the main emphasis was naturally placed on the atmosphere surrounding the town or city because, of all the factors which might be responsible, it was considered to be the most important.

The presence of human excreta can very quickly render the atmosphere extremely unpleasant but Mohenjo-Daro and Harappa, the two cities in the Indus Valley, Kish, the

Sumerian city in Mesopotamia, Chorsabad of the Babylonians, Knossos in Crete and Akhetaton in Egypt, which flourished between 3,000 B.C. and 1,000 B.C. show evidences that they took considerable care to achieve its prompt disposal.[1] The early Greeks may not have been quite so advanced but modern water closets of somewhat later date than the Heroic Age have been found at Priene and Miletus in Asia Minor. The Romans displayed almost as much talent for the disposal of the waste products of their metabolism as they did in the provision of water. Each house had its *latrina*. Some of them were quite large, for it was apparently the Roman custom to answer the calls of Nature in company. Long benches of brick or marble were provided, possibly with wooden covers, the top slab being pierced with holes beneath which was a running stream of water. No attempt was made to construct cubicles or to pander to any desire for privacy. Indeed, at Timgad, there were, in one public convenience, no less than 26 carved stone seats with dolphins as ornamentation. Something similar has come to light at Dougga, also in Northern Africa.

Probably because so many of the common people of Rome had to spend most of their time in the streets, public latrines were also provided, there being no less than 150 of them at the time of Constantine. Vespasian even went so far as to use them for purposes of revenue, and taxed them, a proceeding in accord with the character of one "whose virtues were disgraced by a strict and even sordid parsimony".

The sewage from the *latrinae* usually passed first into cesspools, which became in effect septic tanks, and it was only the effluent from these which found its way into the sewers. These sewers were the glory of Roman sanitation and

were so numerous that Pliny was moved to remark that the city was "*urbs pensilis*". They were large, Agrippa having to use a boat to explore them, a height of 14 feet and a width of 10 feet 6 inches being by no means exceptional. They even had their representative on Olympus, whose amours were apparently not confined to immortals.

> "Then, Cloacina, Goddess of the tide,
> Whose sable streams beneath the city glide,
> Indulged the modish flame; the town she roved;
> A mortal scavenger she saw, she loved."[2]

They were actually adaptations of the sewers put in by the Etruscans to drain the swamps of the lower lying parts of the town about 600 B.C. They did not lead to the unlovely areas of sewage farms later generations conceal somewhere on the outskirts of their cities; the effluent was gathered into a great "*receptaculum omnium purgamentorum urbis*", or *Cloaca maxima,* through which it emerged into the Tiber and which is still visible to-day.[3]

Sewers or other methods for the prompt disposal of excrement were invariably installed wherever the Romans went, and even far distant Housesteads on Hadrian's Wall had latrines flushed by running water from storage tanks or surface water.

Ample water supplies can also help to purify the atmosphere and the history of the higher hydraulics goes back at least as far as the time of Mohenjo-Daro and Harappa, where brick-lined wells provided ample water supplies for a population which was evidently much addicted to bathing. An aqueduct constructed in the sixth century B.C. by Pisistratus for the inhabitants of Athens, the fourteen aqueducts which supplied the fountains and enormous baths

of the Romans, and the two great underground reservoirs constructed by Justinian in the Constantinople of the sixth century A.D., all show clearly that for well over a thousand years ample supplies of water for all sorts of purposes could be made available in even the largest cities.

Other expedients for the improvement of the atmosphere were also employed. There is, for instance, a possibility that Empedocles and Acron adopted the heroic expedient of closing mountain gorges through which the wrong type of wind was blowing on to the plains below, and producing epidemic disease. Fire too was considered a useful prophylactic and Hippocrates is said to have advised the lighting of fires in Athens during its Plague, which was considered at the time to have been brought on by a failure of the Etesian winds. Scents too might be valuable as neutralizing agents and Commodus during a recrudescence of the Antonine Pestilence seems to have retreated to Laurentium on the advice of his physicians in the hope that the scent of the laurels there might protect him against infection.

With the downfall of Rome and its ordered government replaced by the chaos of the Dark Ages, the larger undertakings referred to above and which it must be confessed were already in need of extensive repair, gradually went out of action. The privy, the bucket or possibly nothing at all replaced the *latrinae* of the Romans and the shallow well or the nearest stream became their only sources of water.

But the doctrine of atmospheric derangements as a prime cause of disease still persisted, the School of Salerno epitomizing existing knowledge in the couplet:

> "Though all ill sauours do not breed infection
> *Yet sure infection cometh by most smelling.*"[4]

Odours of all kinds, but preferably bad ones, were therefore sought for and, if possible, eliminated in some way. For many reasons, these attempts do not seem to have been particularly successful, but they were at least made. London, for instance, attacked them by statute. The first onslaught of this description appears to have been directed towards the pigs which the citizens insisted on keeping within the city. In 1281 swine found in the streets were to be impounded and in 1297 pigsties which had been erected in the streets were to be removed and all errant pigs forfeited. The slaughter houses were next attended to, in 1283 the melting of tallow in Chepe was forbidden, and in 1310 the flaying of dead horses. In 1371 the authorities became almost revolutionary for the slaughter of large animals was prohibited in places nearer to the city than Stratford le Bow and Knightsbridge. In course of time, other potentially offensive trades also received attention, but although the atmosphere may have been slightly improved, it is improbable that much disease was prevented.

Legislation was also introduced in an attempt to discourage the inhabitants of London from disposing of night soil and excreta by the simple process of throwing it out into the street. Accordingly, the owners of houses were warned as early as 1297 that they must clean the streets in front of their property. In 1309 interference with the liberty of the subject went even farther and it was laid down that filth "ought to have been carried to the Thames or elsewhere out of town".[5] The first part of this order seems to have been obeyed all too thoroughly, and with consequences that even a mediaeval legislator might have foreseen. For the Thames is a tidal stream, so that a dead dog thrown in at Westminster is carried backwards and forwards by the ebb

and flow of the tide for so long a time that it has almost ceased to be recognizable as a dog when it finally reaches the purifying winds of the Nore. Because of this, the filth accumulated at Dowgate Dock in 1345 made Thames water no longer serviceable, and the City put in scavengers to cleanse it and to keep it clean. There were, however, repeated backslidings and in 1388, Parliament made an attempt to improve matters by the passage of the first Statute dealing specifically with public health, which forbids the disposal of all putrescible materials—identified as Dung, Garbages, Intrails and other Ordure—by throwing them into the nearest street, water course or waste ground.[6]

Partly because of the shortage of water, personal ablution had become unusual and a bath almost unknown. Michelet's aphorism "*Mille ans d'histoire mais pas un seul bain*" was only too true. But even if one does not wash one must drink and rather inadequate supplies of water were actually brought to many European towns and cities during the Middle Ages. These undertakings were, on the whole, sadly lacking in efficiency because the only water mains known were hollowed logs driven end to end whose joints leaked so profusely that about a quarter of the water never reached a consumer.[7] And probably because of the expense only a comparatively small proportion of the inhabitants in the areas served had water in their own homes. Even so recently as a hundred years ago, about 300,000 out of the 900,000 persons in the area of the New River Company did not have the blessings of a tap in their houses. Indeed 640,000 persons in 1850 living in London had to rely on stand-pipes in the streets, which only provided water at intervals. If it was poor in quantity it was little better in quality. Much of it came from the Thames between London Bridge and

Hammersmith. In 1827, the inhabitants of Westminster were provided with water which was "in a state Offensive to the sight, Disgusting to the imagination and Destructive to the Health."[8]

Thus, until comparatively recent times, few towns or cities had succeeded in eliminating the most important sources of the odours, that the majority of their inhabitants still firmly believed to be the cause of pestilence. The wide gap between theory and practice might have been allowed to continue for some considerable time had not cholera appeared in 1831 and spent the better part of a year travelling without inhibition from end to end of England. As might have been expected, the poorer parts of the towns were hit the hardest but there was always danger that by some mischance the infection might spread to the more prosperous quarters of these towns. And as it was extremely probable that the disease would in no long time return, a Board of Poor Law Commission was accordingly appointed in 1832 to examine the conditions in the poorer parts of the great cities. A member of the Commission was a lawyer named Edwin Chadwick who, stimulated by Jeremy Bentham, forsook jurisprudence and made it his life's work to galvanize his countrymen into writing a new page in the history of hygiene.[9] His equipment for the task was meagre, consisting of a complete inability to suffer fools gladly and a hatred of all forms of vested interest. With these talents and no instruments other than his eyes, nose and larynx, and deplorably ignorant of the statistical or even the experimental method, he ferreted out what a modern civilization would describe as stinks, with such extreme enthusiasm that he caught and nearly succumbed to typhus.

He was undoubtedly the mainspring of the Board although he was aided considerably by Neil Arnott, James Philip Kay and Southwood Smith. Reports were issued from time to time, and in 1842 came his *magnum opus*, the *Report on the Sanitary Conditions of the Labouring Population of Great Britain*, which details with few inhibitions the dirty, overcrowded and insanitary conditions in which the poor were living. Unlike most publications of this sort, it was not only read but acted upon. This strange circumstance was due partly to the fact that its author was an amateur, the English having always looked with suspicion on the professional; partly to its considerable intrinsic merits; partly to the existence of a new middle class which had been stimulated by the novels of Dickens and Kingsley, and by the new morality of Pusey and Lord Shaftesbury, to reforming impulses denied to its predecessors; and perhaps most of all, to the fact that there even seemed to be money in it. For once it was assumed that there was a connection between poverty and sickness, it seemed obvious that a great deal of the money required for the alleviation of distress under the Poor Law would be better and more profitably employed in improving the environment of the poor, and preventing the sickness which was otherwise inevitable.

Although the financial aspect of the matter may have carried weight with parliaments and parish councils, the principal factor in achieving the subsequent spring cleaning of our cities was Chadwick's ability to overcome opposition. Though *The Times* stated categorically that "the English people would prefer to take the chance of cholera rather than be bullied into health", by one means or another they were bullied into providing a great deal of money to improve the lot of their fellow men.

Probably because the Industrial Revolution got under way sooner in England than in most other countries, the movement for reform came earlier, and gained momentum more quickly because the need was greater. But it was by no means limited to England. In America, for instance, Lemuel Shattuck of Boston laid before the legislature of the State of Massachusetts, as early as 1850, his *General Plan for the Promotion of Public and Personal Health*, which voiced much the same opinions as Chadwick about the connection between poverty, environment and disease.

In Germany, too, Rudolph Virchow, destined later to become the foremost pathologist of his time, came to a similar conclusion following his investigation of an outbreak of relapsing fever in Upper Silesia. The fact that it followed the collapse of the textile industry, with consequent unemployment, dirt and overcrowding, convinced him of the connection between environment and disease, and he accordingly devoted the first editorial to this theme in his new journal *Medizinische Reform* in 1848.[10]

Because cholera was still considered to be due to odours and emanations, which Chadwick and his colleagues had shown to be present in such abundance in the meaner portions of the great cities, it was obvious that their elimination was the first necessity. This required many reforms but principally an adequate supply of water and the installation of facilities for the prompt and efficient disposal of sewage.

The provision of water for the inhabitants of great cities was an engineering problem requiring little more than adequate supplies of money. But when the part played by water in the dissemination of cholera and typhoid had become obvious, the purity of these supplies also became a matter of importance. Filtration through sand, first used

by the Chelsea and Lambeth Companies in 1829, and, much more recently, treatment with chlorine have been so successful in removing microbes from the water supplied to great cities that it is a poor water which contains more than one *Bact. coli* in as large a quantity as 100 c.c.

By comparison, the prompt and efficient disposal of the sewage of great cities and industrial towns was a much greater problem. The privy or the cesspool previously almost universal in the poorer parts of the towns, had only been emptied infrequently, if at all. Even when they were replaced by water closets, the sanitary reformers were faced with many problems. Previously, whatever drains existed had been constructed mostly for the disposal of rain water and had therefore merely emptied into the nearest water-course or the sea, and for a time they continued to do so. When they were called upon to carry sewage their new contents naturally made their outfalls exceedingly unpleasant, to the great discomfiture of those people known in law courts as riparian owners. Although the sanitary reformers could claim with pride that during the 1860's they had abolished no less than 200,000 cesspools in the Metropolis and 51 at Windsor Castle, they were faced with the undeniable fact that the Serpentine had become an open and stinking sewer. The Thames, too, when called upon to absorb the London sewage at Barking, began to smell seriously and, in 1858, produced what contemporaries described as the Great Stench. Even the hallowed precincts of Government were affected by it and legislators in the House of Commons were forced to carry on their deliberations behind windows protected by blinds saturated with chloride of lime. The solemn processes of the law, too, were on occasion seriously impeded by odours wafted from the

reeking Thames through the Temple into the Law Courts. Many travellers with more regard for their health than desire to reach their destination on time, made wide detours rather than cross the lower bridges across the river. Nor was this state of affairs confined to the Metropolis. Certain rivers in Yorkshire were reputed in 1868 to "have the appearance of ink," and of being "little better than a local drain."[11] The disposal of the large volumes of sewage became, therefore, something in the nature of a National Emergency, and exercised the talents of the highest in the land. The Prince Consort, among his many other activities, invented a scheme which was both simpler and more economical than others previously suggested. But as it defied the laws of gravity, nothing further came of it, and his contemporaries had to content themselves with the simple expedient of allowing the sewage to flood low-lying ground through which the water drained away, leaving the solid materials behind. This was objectionable for many reasons, but for several decades it was the best they could do. But in the 1890's, Sutton in Surrey distinguished itself in the history of sewage by installing the new apparatus invented by Mr. Dibdin, in which the bacteria present in sewage consumed the unpleasant materials in it; and by way of relief from the discussion of the vagaries of filter beds and their like, visiting deputations could at certain seasons of the year also inspect the ample crops of Mitcham lavender the Sutton sewage produced. With this the history of sewage, for all practical purposes, ends because all subsequent installations have made use of the same principle.

While these reforms were in progress, other schemes for the betterment of our cities were set on foot. Slum clearance received attention because it was obvious that water and

drains alone would not suffice when large families were forced to live in one room with little or no ventilation. The worst evils of industrial housing were prevented by legislation, which made it compulsory for the plans of all new dwellings to be passed by the local medical officer of health. Refuse and garbage collection was instituted and made a charge on the community. Roads and lanes were paved, and lighted at night. Parks and open spaces were provided for air and recreation. And in many other ways the environment in which the greater part of the population had to live was greatly improved.

At the same time, their place of work received attention, and numerous factory acts laid down minimum standards of safety, of lighting and ventilation. Hours of work were regulated, for it was realized that under free enterprise, with no unemployment benefit and a large pool of unemployed waiting for work, employers showed a marked tendency to exploit the workers. Dangerous trades too received attention and efforts were made to minimize the risks to which the workers were exposed.

There is no doubt that we of this century owe a great debt to Chadwick and his colleagues. They gave us clean, odourless cities, free from typhoid, dysentery and cholera. But it is as well that we should realize that because no one knew exactly how cholera and typhoid were transmitted, they fell back with single-minded devotion on the Greek hypothesis that the environment could produce disease. Fevers of all kinds, so their reasoning ran, were commoner in poor, overcrowded, ill-ventilated and insanitary dwellings. Therefore, something came from the foulness with which the inhabitants were surrounded, was inhaled by them, absorbed by their lungs and injured them in such a way as to produce

disease. If anyone doubted their hypothesis, they could actually produce evidence that people had been overcome and some had died from gases produced in sewers.

We now know that the gas in question was hydrogen sulphide and although it can, if in sufficient concentration, kill one it cannot produce typhoid. But this was beyond Chadwick, who laid it down clearly that "the various forms of epidemic, endemic and other diseases caused, aggravated or propagated chiefly amongst the labouring classes by atmospheric impurities, are produced by decomposing animal and vegetable substances, by damp and filth and close and overcrowded dwellings."[12] This reasoning is no different from that enunciated (in far better language) by his chief lieutenant Simon in 1849, when speaking of effluvia. "Whence these may be derived signifies little, whether the matter passing into decay be an accumulation of soaking straw and cabbage leaves in some miserable cellar, or the garbage of a slaughter house, or an overflowing cesspool, or dead dogs, floated at high water into the mouth of a sewer, or stinking fish thrown overboard at Billingsgate dock, or the remains of human corpses undergoing their last chemical changes in consecrated earth; the previous history of the decomposed material is of no moment whatever."[13]

This, of course, we now know is nonsense. Emanations of these types do not cause typhoid or dysentery. But though the doctrine on which they operated was erroneous, Chadwick and Simon cleaned our cities for us, and in time prevented a great deal of disease.

The rival theory, that disease might be due to something one acquired as a result of fairly close contact with an infected person, also provoked certain reactions on the part

of the community. For a very long time, these reactions consisted of measures for the avoidance of this contact. This might involve either the flight of the healthy from those known to be infected, or the removal of the sick from the immediate neighbourhood of those not yet infected.

No one, except possibly Galen, seems to have attempted to secure immunity by precipitate retreat from pestilence until the Black Death brought plague to Europe. But this became the standard practice during all the succeeding epidemics of the disease. Even the highest in the land showed little heroism on these occasions, and most European monarchies put as great a distance as possible between themselves and their afflicted subjects.

The English court was no exception, and when the plague appeared in the City of London with any severity, it retired hastily to Hampton Court or Windsor, and forbade all travellers from London to enter its presence. Elizabeth did not stop at mere prohibition, for "a gallows was set up in the market place of Windsor to hang all such as should come there from London. No wares were to be brought to, or through, or by Windsor; nor any-one on the river by Windsor to carry wood or other stuff to or from London, upon pain of hanging without any judgement—and such people as received any wares out of London into Windsor were turned out of their houses and their houses shut up."[14] The Venetian ambassador was constantly complaining that, having remained at his post in London, he was unable to obtain an audience when affairs of state required it.

Even the young United States adopted the practice, for President Washington found it desirable to retreat to

Mount Vernon with nearly all his government officials when yellow fever came to Philadelphia in 1793.

The Papacy, too, generally retreated when plague appeared; Nicholas V in 1449 went to Umbria, Pius II in 1462 to Viterbo, Boliena and Corsignano, in 1476 Sextus IV carried out a veritable *wanderjahre*, and in 1522 Adrian VI anticipated Borrow by carrying his Bible into Spain.

Parliament was no exception and it followed a peripatetic existence in various southern counties whenever plague became threatening. The universities were similarly discommoded and the higher learning at Oxford had to disperse at least thirty times during the fifteenth century.

Even the medical profession was disinclined to indulge in heroics. Galen ran away from Rome on the arrival of the Antonine Pestilence, and Fracastor fled from Verona to Incaffi to escape an epidemic of typhus. During the Black Death, the physicians of Venice fled in a body, leaving the more heroic surgeons led by Andrea di Podova without opposition. Those of London appear to have behaved in the same way during the plague of 1603, for Dekker complained: "Never let any man aske me what became of our Physitions in this Massacre; they hid their Synodicall heads as well as the prowdest; and I cannot blame them, for their Phlebotomies, Losinges, and Electuaries, with their Diacotholicons, Diacodions, Amulets, and Antidotes, had not so much strength to hold life and soule together, as a pot of Pindars Ale and Nutmeg."[15] Even Sydenham made a precipitate retreat from London in 1665, although in time he apparently thought better of it and returned to London where "on account of the scarcity of abler physicians I could not avoid being called to assist the affected".

With such examples it is hardly surprising that the laity—or that part which was financially in a position to do so—left town immediately in time of plague. Many had retreats earmarked for the purpose, in which they remained until the danger was over. The tradespeople and the working classes had no such luxuries. They had to remain and take their chance. But the plague was by no means their only worry. Retail and wholesale trading usually stopped altogether. Unemployment, which in those days usually meant starvation, became general. Probably because of this, Arab merchants caught in Cairo or Alexandria in time of plague shut themselves up in their houses but succeeded in keeping the channels of trade open by shouting from the house tops or, with more danger of infection but in greater secrecy, through barred windows on the ground floor.

Rapid retreat, therefore, by all who were financially in a position to do so was the rule all through the great outbreaks of plague in the fourteenth, fifteenth, sixteenth and seventeenth centuries. It was evidently contemplated so recently as 1832 when cholera came to London. Indeed, Wellington expressed himself quite strongly on the subject: "I told Lord Grey at Windsor that I was quite sure if three or four hundred Notables were to leave London for fear of it, they would be followed by three or four hundred thousand, and that then this country would be plunged into greater confusion than had been known for hundreds of years."[16] Whether it was because the men of that century were somewhat more courageous, or cholera appeared to be less deadly, or because the Reform Bill had passed the Commons for the third time and there was quite a possibility that a number of Notables would be required in town to secure its passage by becoming

Peers, the fact remains that there was no mass evacuation of London or the great towns.

A second expedient was to reverse the above process. Instead of the healthy removing themselves, the infected were isolated. Practices of this nature are of very respectable antiquity particularly in the case of leprosy. The Assyro-Babylonians expelled their lepers 3,500 years ago and there were very precise instructions for the disposal of lepers in the Mosaic Law. When the disease appeared in Europe on the heels of Ptolemy's army, fresh from its victories in Egypt, little seems to have been done at first to prevent its dissemination. Possibly because of its Biblical associations, its control, beginning with the Edict of Lyons in 583, became an ecclesiastical responsibility. In the process it became an extremely uncharitable proceeding, the leper being cast out of society after a ceremony of the same order of gloom as that associated with the unfrocking of a priest. As they had nowhere to go, such outcasts were in time provided with lazarettos which appeared in Metz, Verdun and Maestricht as early as the seventh century. When the Franciscan order was founded in the thirteenth century, one of its principal activities was the care of these unfortunates. Europe eventually had no less than 19,000 lazarettos where the lepers could be cared for by priests who were lepers themselves. If the inmates emerged into the outer world, they were dressed in a distinctive manner with a large enveloping cloak. They were forbidden to speak above a whisper, their progress was punctuated by a bell or rattle and they had to point to objects they required when making a purchase. Even so, there were some who considered these measures inadequate, and in 1313 Philip the Fair of France went so far as to order the burning of all the lepers in his realm.

Whether it was some change in the organism or in the hosts or because leprosy requires prolonged contact before infection can be acquired, it gradually disappeared from Europe and by the end of the sixteenth century it had gone.

When the Black Death came to Europe and the infectious nature of the disease had been recognized, it was not very long before measures similar to those employed for lepers were taken, to prevent the spread of the infection from patients suffering from the disease. They obviously could not be treated in quite the same way as lepers, because patients with plague are very seriously ill indeed. They have to take to their beds, and require some nursing if they are to have any chance of recovery. As there was usually nowhere to send them, they were obliged to remain at home, but steps were taken to prevent contact with the outside world. Many primitive tribes have adopted this practice in any form of illness. The Tartars adopted the expedient long before the western world and in the process invented the unlovely placard beloved of American medicine: "When a man is sick, he lies in his bed, and causes a sign to be set upon his house, to signify that no man may enter into his house: wherefore none at all visit any sick person but his servant."[17]

When plague came to Europe something of the same sort was instituted, the patient, together with all his family and servants, being compulsorily isolated within their home. The Milanese were more thorough than most, for they actually went to the length of walling up the windows and doors of the first house in which plague occurred, along with the inhabitants. The latter died either of the disease, of suffocation or of starvation, but it is on record that this

singularly cruel practice sufficed to prevent further cases for some time thereafter. In 1629 the town of Digne in France, being afflicted with typhus, was treated in somewhat similar fashion. The gates were closed in June of that year on a population of about 10,000, and troops stationed to prevent anyone leaving. When the town was reopened in June 1630 there were only 1,500 survivors, of whom all but five had had the disease and recovered. In the same category is the little village of Eyam in Derbyshire, which voluntarily shut itself off from the world during the plague of 1666 with, after a year, only 30 survivors out of a population of 350.

Other towns and countries were less thorough. Berlin, for instance, in the plague years of 1576, 1584 and 1598, contented itself with iron chains and guards posted across the entrance to streets in which there were infected houses. In England the usual expedient was the "shutting up" of houses in which there were patients suffering from plague. This was initiated in 1518 when Sir Thomas More ordered the Mayor of Oxford to see to it that those who became infected were to "keep in, put out wispes, and bear white rods". By 1543, the sign of the cross on the front door had become the rule, with quarantine of the inmates for forty days. The colour of the cross suffered several tinctorial metamorphoses; it was blue when first introduced, but in course of time it became white in Germany and red in England with, for good measure, the subscript "The Lord have Mercy" as well.

By the time of the Great Plague of London, the system had become standardized. The diagnosis of the disease first being made by a searcher, the house was then "shut up" with all who were in it, the cross and subscription were

placed on the door, and a guard posted to see that the inhabitants did not emerge over a period of forty days. It was in many ways a harrowing experience for the prisoners, whose sufferings were adequately described by Defoe, while the system itself was roundly condemned by Richard Mead.

A more humanitarian system would have been to have taken the patients to some form of isolation hospital, where they could be looked after and at the same time kept from harming their fellow men. This, however, was easier said than done, for in the Middle Ages there were very few hospitals of any kind, and the few that did exist were mostly places in which to die. None of them was suitable for the isolation and treatment of infectious diseases. There were, it is true, the lazarettos scattered throughout Europe, which had been built for the housing of lepers and which, with the eradication of that disease, were becoming available. But they were quite inadequate for the care and treatment of the large number of patients in any plague epidemic.

Nevertheless, official thinking certainly felt that hospitals should be provided. Sir Thomas More in his *Utopia* was clear on this point, and Queen Elizabeth in 1583 was quite indignant in a letter to the City of London, marvelling "how slenderly you respect the preservation of your own lives."[18] They seem to have taken some, if inadequate, notice, for one, but only one, pest house became available by 1665, when the Great Plague came.

In some places, small buildings were erected for the reception of these patients, one in particular still surviving at Odiham, being no more than a small shed, with a floor sunk two feet into the earth to prevent the spread of infection

to the outside world, and conveniently placed in one corner of the churchyard.

The more advanced municipalities, however, went very much further, and real attempts were made to cope with the flood of patients to be expected in time of plague. As early as 1423, Venice had built on the Island of Santa Maria di Nazaret, a lazaretto, supplied with necessities as a first charge on the revenue from salt, and a second was established in 1576 on the island of Sant' Erasmo, but in general it was necessary to build new hospitals or convert existing buildings when the great outbreaks appeared. For this reason, during the plague of 1576 in Milan the great hospital of St. Gregory was used along with six temporary wooden lazarettos outside the walls, and in 1656, the Isola Tiberina—which had, centuries before, formed the headquarters of Aesculapius in Rome—was converted into a hospital for plague victims.

In communities which had no accommodation for their patients, it was still felt that they should be put out of harm's way. Visconte Bernabo of Reggio in 1374 ordained that those infected with plague were to "be brought out of town, to the fields, there to die or recover".[10] Some two centuries later, Edinburgh followed suit and infected families were ordered to move out to the health-giving breezes of the Burgh Moor, where they were accommodated in wretched huts in charge of two officials known as Bailies of the Muir, their clothes being purified by boiling in a large cauldron erected in the open air.

Although attempts were made during the great outbreaks of plague to provide some form of hospital accommodation for a proportion of those infected, there were very few, if any, facilities for the isolation of other forms of infectious disease. Even smallpox had to be nursed at home. When

isolation hospitals did appear, they were first called Houses of Recovery, probably to distinguish them from the Pest Houses, which had been used for plague and where recovery was the exception rather than the rule. In time, they became known as Fever Hospitals and during the nineteenth century began to appear on the outskirts of the cities and towns of Europe. They were invariably of forbidding aspect and in the windiest areas available. Here, in an atmosphere redolent of carbolic and cleanliness, the sick could be adequately looked after, and after recovery and abundant ablution, returned to the bosom of their families.

It is, of course, obvious that unless steps are quickly taken to notify the authorities of the occurrence of any form of infectious disease, the situation may get completely out of hand within a few days. And because of the unfortunate consequences, it is not unknown for doctors who have diagnosed a case of infectious disease to be frowned on not only by the patient and his friends, but by the municipality as well. It requires only a few cases of typhoid or poliomyelitis in a health resort during the season to ruin business for that and sometimes subsequent years as well. Nevertheless, infectious diseases seldom pay much attention to balance sheets. A policy of *laissez faire* usually reaps its own reward. Certainly the entry of plague into California and its subsequent transmission to the wild mammals of the Western States in 1900 might possibly have been checked, had it not been for a strange obtuseness on the part of the Governor to recognize the fact that his State had been invaded by so unpleasant and un-American a disease.

The earliest measure along these lines seems to have been the appointment of Searchers in London, during the sixteenth century, whose duty it was to inspect all dead bodies

and ascertain whether they had died of plague. In time, they extended their studies to the living and attempted to ascertain whether suspected cases of severe disease were or were not plague. When public health became properly organized, this duty devolved on the doctor, and in order to make it slightly more attractive, he was actually paid a fee for every notification.

In the above instances, it was hoped to prevent the further spread of an infection which was already present somewhere in the community. But it had been observed during the outbreak of plague in the sixth century that countries might remain free of the disease until the arrival of a boat carrying the infection. It probably reached Constantinople, for instance, in grain ships from Alexandria, and during the Black Death, the same process was observed, the disease being obviously transported in galleys from the Crimea to Venice and Genoa. Permanent closure of the port might keep plague away, but it would ruin its commerce. It therefore became necessary to provide a check capable of preventing the importation of infection while keeping open the channels of trade. The check devised was the measure known as quarantine. The word was derived from the *Quaranta giorni* both Christ and Moses spent wandering in the desert, and meant the detention of travellers and their goods in special buildings or lazarettos for forty days, so that if plague was incubating in their persons, or present in their belongings, the compulsory stay would allow the disease to develop in the victims themselves and permit of the purification of their clothing and their goods. Ragusa in June 1377 seems to have been the first port to set up such a station, Marseilles followed six years later on the Island of Pornique, and other Mediterranean ports quickly took

similar action. Britain seems to have been a little slow, although the island of Inchkeith in the Firth of Forth did duty as a quarantine station. London, stimulated by the fact that plague was rampant in Lisbon in 1500, prevented seamen from landing, and in 1625 caught up with the times by setting up a quarantine station.

For these reasons, maritime travel could be quite exciting, for on arrival at a new port, one was never certain with what degree of enthusiasm the authorities might view the vessel or its contents. If it had come from an uninfected locality, all was well, and it was given a clean bill of health. If, however, its port of origin was without blemish but it had had the misfortune to call somewhere which was infected, it was regarded as touched. One degree worse was a vessel which had no actual sickness on board, but whose cargo had come from an infected locality. Such a boat was regarded as suspicious. Worst of all, and classed as unclean was the vessel with actual cases of plague on board.

In such an event, the subsequent proceedings were the reverse of charitable. The passengers and crew were faced with prolonged detention. The cargo, however, was treated according to its composition. Such articles as wool, hair, cotton, linen, hemp, silk and thread, were considered to be capable of conveying infection. So, too, were the sacks, baskets, boxes, casks and the cords used for wrapping them. On the other hand, metals of all sorts, arms, cooking utensils, precious stones and marble, grain, flour, meal, vegetables, fruit, nuts, wine, oil, vinegar and all forms of drugs and aromatics were considered less capable of carrying infection.

There is no doubt that the Mediterranean nations took

quarantine very seriously. There is an interesting summary of the experiences of different travellers in a little publication by Dr. Eager.[20] But by far the best report is that of John Howard, who minutely inspected several quarantine stations in the Mediterranean towards the end of the eighteenth century. He even went so far as to sail from Smyrna in a plague-infected ship so that he could have himself immured in the quarantine station at Venice, and in this way ascertain exactly what occurred in them. His account of this experience, which is unfortunately too long to quote, shows what extreme, and to modern eyes almost ludicrous, precautions were evidently considered necessary at a time when the true mechanism of the transmission of plague was quite unknown and unsuspected. In the process little regard seems to have been paid to the comfort of those held in custody. Howard eventually found himself in a "room the walls of which had probably not been cleaned for half a century," and which gave him such a headache that he was unable to sleep. Washing with boiling water proving useless as a deodorant, it was not until he had had the walls whitewashed that he was able to live in it with any comfort.[21]

Since the fifteenth century, medical control of marine communications has never ceased, even though plague no longer troubles the Mediterranean. Every incoming vessel at almost any port in the world is invariably required to produce a clean bill of health before it is allowed to dock or land its passengers. Exactly the same precautions are taken over long distance aeroplanes, whose passengers are required to report any deviation of their health from the normal for some period after their arrival.

When parasites were at last discovered, their sources

ascertained, and the routes by which they reach human beings clearly demonstrated, the extreme measures employed in the imposition of maritime quarantine, mostly out of ignorance, could be considerably relaxed with no diminution in efficiency.

With the recognition by Semmelweis that puerperal sepsis was due to infection of the placental site by something conveyed on the hands of the obstetrician, and with, some time later, Lister's discovery that infection of wounds was due to the introduction of something (later shown to be micro-organisms) on the hands, instruments, or even in the air which entered the wound, new methods were introduced which revolutionized both obstetrics and surgery in the space of about twenty years. The first of these measures was the thorough cleansing of the hands of obstetricians in chlorine water, a practice which reduced the puerperal sepsis rate in Vienna from 11·4 per cent to 3 per cent in the space of about a year.[22] The second was the immersion of all instruments, dressings and even the hands of the operator in carbolic acid when treating open wounds or carrying out surgical operations. Indeed, Lister went even further and operated for years in a cloud of steam impregnated with carbolic acid, in order to sterilize the air entering wounds.[23]

When organisms responsible for surgical and obstetrical sepsis were recognized in the 1880's, it was possible to do away with some of the more bizarre techniques employed in antiseptic surgery, and to substitute the modern aseptic methods which survive in all essentials to this day. In consequence, the entire habitat in which the surgeon works has undergone a radical transformation. Operating and delivery rooms nowadays possess most of the appurtenances

of temples, and the operation itself is conducted with much of the mystery and ceremony of a religious rite. Everything which comes into contact with the open wound has passed through an ordeal by fire, boiling water, strong chemicals or sterilizing vapours. The surgeon himself long ago abandoned the blood-stained frock coat of his forefathers, and is almost completely enveloped in sterilized robes. No longer does he wipe his hands on his trousers or a dirty towel before operating, but after washing them with extreme care, encases them in rubber gloves. But hospital gangrene, which once rendered even the simplest operation an extremely perilous undertaking, has disappeared, and puerperal sepsis is almost a thing of the past.

The basic methods necessary for the prevention of diseases in which faecal discharges contaminate a water supply—that is, typhoid, cholera and dysentery—had already been evolved on the theory of Greek miasmas and the like. The isolation and recognition of the causative organisms merely demonstrated that these techniques were, as it happened, the right ones. But much could then be done to put them on a firmer and more scientific basis. The disposal of sewage, for instance, could be quickly and efficaciously performed with the production of a harmless and unobjectionable effluent. Water supplies to our great cities became subject to constant bacteriological control, and while filtration through sand had been employed many years before microbes were seriously considered as causes of disease, other, more efficacious methods such as chlorination could now be introduced. In the case of these diseases, it was, however, in the recognition of the importance of the carrier in the dissemination of infections that bacteriology played its most important and significant role.

The fact that the milk of cows can transmit infection to human beings was not discovered until after the birth of bacteriology. It led directly to attempts to eradicate those infections, and particularly bovine tuberculosis, amongst dairy cattle. It also led to methods such as pasteurization, by which sufficient heat is applied to the milk to kill the dangerous organisms likely to be present in it without harming its nutritive and other qualities.

In the case of diseases transmitted by mosquitoes, such as malaria and yellow fever, the first necessity was identification of the particular species responsible, and then a study of its breeding habits and its range of activity. With this information available, it became possible to embark on schemes for denying the mosquitoes access to infected and uninfected individuals, and even to prevent them from breeding at all. Careful screening of sick rooms, and of the houses in infected areas, was instituted. The eradication of the mosquito problem is a much more formidable problem. All, however, are most vulnerable in their larval stage when they are developing in water. Various expedients have been evolved to deal with the larvae. One of the most obvious is the elimination of the particular type of water in which they breed. In the case of some species which prefer pools or puddles, water butts, tin cans or other forms of still water, much may be done by drainage etc., by the use of a poison such as paris green or D.D.T., or by suffocation of the larvae by spreading oil on the surface of the water. By the application of such relatively simple methods much has been done towards the eradication of yellow fever in the Caribbean and malaria in such countries as Macedonia, Cyprus and Sardinia. Unfortunately, other mosquito hosts are less accommodating. Some are able to grow in running

water and others, such as *Haemogogus*, which carries jungle yellow fever, breed in the tops of trees where they are virtually inaccessible. Nevertheless, there is no doubt that much may be done towards the prevention of yellow fever and malaria by the elimination of the insect vector. But, and this is perhaps the most important point, all schemes aiming to do this were, until quite recently, very expensive, and many communities in which these insects are common and the diseases they carry are prevalent, are not in a position to help themselves very much.

The discovery that epidemic typhus was carried by the body louse also pointed a way towards the control of this disease by ridding the infected population of these insects. This is not easy, for it necessitates a thorough cleansing of the skin and hair, to eliminate the lice and their eggs, which may be present on the body or on the clothing. Delousing stations came into being during the Serbian epidemic of 1914–15, and were used extensively by both the Central and Western powers during the remainder of the 1914–18 war. They were also employed during the early part of the second world war but were replaced, in 1943, by liberal applications of D.D.T.

The control of infectious disease is, on the whole, something in which the individual can do very little by his unaided efforts. It is a task for governments and international bodies armed with extensive powers and a great deal of money. Some of the first efforts were actually made during the Middle Ages, notably the imposition of maritime quarantine. But it was not until cholera came to Europe in the nineteenth century that any real efforts were made to set up government agencies for the attempted control of infection. Dr. W. H. Duncan was appointed Medical Officer

of Health for Liverpool in 1847 and Dr. John Simon of the City of London only a year later. But for a time the legislation supporting them was tentative and, on the whole, very inadequate, and it was not until the passage of the great Public Health Act of 1875 that any decisive step was taken to put matters on a firm enough basis. Britain can take legitimate pride in this Act, for it was the model on which similar measures passed in other countries were based, and so essentially sound was it that despite the advances in knowledge which came after it had become law, the next Act was not required until 1929.

Acts of this nature only dealt with the prevention of infection and disease within a single country. They played no part in international control. But in view of the speed with which cholera had spread from India in the early part of the nineteenth century, and the threat to the maritime nations of the world of the recrudescence of plague at the end of the century, it was felt that some international body was required which would control the spread of these diseases.

Despite many international conferences little or nothing was done until 1907 when the *Office International D'Hygiene Publique* was formed in Paris. Its main function was to guard the Western countries from such diseases as smallpox, plague, cholera, yellow fever and typhus, which were still more or less uncontrolled in the East. When the League of Nations came into being, one of its more successful offshoots was the Health Section which acted as a clearing house for the epidemiology of the world. Its functions were eventually taken over by the World Health Organization of the United Nations which, despite inadequate resources and either active opposition or frank indifference,

is making what efforts it can, not only to prevent the spread of infectious disease from country to country, but to spread the doctrine of health to countries which up to the present have made little effort to better the health of their subjects.

CHAPTER SIX

THE REACTION OF THE INDIVIDUAL

Of old when folk lay sick and sorely tried
The doctors gave them physic, and they died.
But here's a happier age! for now we know
Both how to make men sick and keep them so.

HILAIRE BELLOC: *On Hygiene.*

IN THE PRECEDING chapter we have dealt with the measures which the community as a whole can take to prevent a great deal of infectious disease. But the individual can also do something to assist in this matter.

In classical times, the Greek theories that disease was due to disturbances in the humours, naturally led to the institution of measures which would prevent the humours from becoming unbalanced, or correcting them if they did so. Close attention was therefore paid to diet, sleep, exercise, movements of the bowels, and so on. Bathing seems to have ranked high in importance, and baths were taken frequently by all but those whom Aristophanes characterized as "poor and dirty". Every house of any size had the necessary facilities, while there were public baths for those who had none at home, and there were public gymnasia with running tracks, dressing-rooms, and plunge baths, staffed with instructors to make Olympic athletes out of the Grecian youth.

In all probability, the Egyptians had subscribed to much the same ideas, for personal cleanliness was regulated by legislation. Some even went below the integument and

voluntarily submitted themselves to emesis and the administration of enemata on three consecutive days in the month. Religion, too, lent its aid by promising health and longevity to those who were clean in body and temperate in habits. And the priesthood set an example by living an almost amphibious existence, bathing every six hours and shaving their bodies every six days.

When the humours got completely out of symmetry and the individual became debilitated or definitely ill, treatment along these lines at home no longer sufficed. The usual recourse was to enter one of the Temples of Aesculapius. Here, the treatment was designed expressly to secure the correction of humoral imbalance. The temples themselves were invariably placed in beautiful situations, with woods and forests for background, well cultivated gardens and fountains within their precincts, and spacious, airy buildings for the votaries. Everything was done that could be done to secure bodily health and peace of mind. The devotees were required to undergo preparatory treatment, which included not only abstinence from wine and food—useful preliminaries in the case of tired business men troubled with their digestions—but exercises in various types of water, such as sea, river or spring. These preliminary hurdles safely passed, the patient was given a final cleansing and after inunction and fumigation was then allowed to enter the sacred precincts. Here he had to undergo the ritual of the incubation sleep, but it is improbable that this did very much to help him. Far more important was the fact that he continued his aquatic exercises, and received more inunctions and massage. In addition, there were gymnasia to provide him with the sort of gentle exercise which is advisable for an elderly corpulent gentleman addicted to good food, and wine. In

order to relieve the tedium of the cure, amusements of various kinds were provided and pleasure grounds for different types of festival formed an important part of the amenities.

Thus, reinvigorated by exercise, diet, abstinence from alcohol and other forms of excess, and residence in delightful and peaceful surroundings, the patient, with his bodily humours at peace with themselves and the world, returned to his business or profession and before many days were passed had once again become the constipated, corpulent, dyspnoeic old tyrant he had been before he entered the temple.[1]

The régime undergone in a temple of Aesculapius was quite severe, entailing complete severance from business and family. It was probably very expensive as well. Perhaps for this reason, the Romans set up establishments in which many of the more mechanical attributes of the Aesculapian system could be obtained, without the necessity for undergoing the rigours of its discipline and complete withdrawal from affairs of State or commerce. These were the great baths which in time became such an important part of Roman life, and which probably accounted for a large part of the fourteen aqueducts eventually owned by the city. Here in the midst of gardens and fountains, the tired business man went through the ritual of the Roman bath, with its *unctuarium*, its *calidarium*, its *sudatorium* where he was thoroughly scraped, its *tepidarium* where in a milieu closely resembling the Pennsylvania station in New York he partook of gentle exercise—stimulated to some extent by the writhing coils of the Laocoon, and then finished the proceedings by total immersion in the *frigidarium*.

When Rome disintegrated and the world subsided into

the morass of the Dark Ages, life became so difficult that luxuries such as temples of Aesculapius or baths on the model of Caracalla became an impossibility. A bare existence was the best that most men could hope for, and the idea of boisterous good health something completely forgotten.

Moreover, personal cleanliness as an end in itself suffered a serious lapse, for in the view of the early Christian Church, cleanliness was by no means next to godliness. Indeed, it was precisely the opposite, for the body was considered to be something base and rather evil, so that measures designed to keep it clean were either futile or actually sinful. Hermits who persisted in avoiding all forms of ablution were considered to be very holy men.

But as the centuries passed, the Greek ideals still survived and if elaborate bodily purification no longer was possible or ecclesiastically desirable, some of the other attributes of the Greek system persisted. Purgation, for instance, was looked upon as important, as was sleep, while blood-letting became popular in order to prevent the body heating with fever. But perhaps the main emphasis came to be laid on diet, and it is noteworthy that by far the greater part of the *Regimen Sanitatis Salernitanum*, which embodies the accumulated wisdom of a great medical school on the subject of positive health, deals with food and drink; not because mediaeval physicians were aware of vitamins, or because their patients were worried about their caloric intake, but because there was a firm belief that certain articles of food were beneficial and others—which to modern eyes seem equally innocent—were harmful, if not actually mortal.

When Europe became civilized again and it became possible to take holidays without the protection of a suit of armour and a troop of horsemen, the virtues of the internal

and external application of water were rediscovered and the temples of Aesculapius came to life again as Spas, which made their appearance wherever the volcanic interior of the earth was kind enough to provide copious supplies of water warm enough for total immersion in comfort.

This, together with frequent blood-lettings and purgation, seems to have been the only attempt made by most of the population towards the fulfilment of the Greek ideals. In any event, it was only the upper classes who could afford either the time or the money to do even this much. The masses generally were living a hand-to-mouth existence and probably never thought of much beyond the day's food and lodging.

During the nineteenth century, however, a radical change took place in England and to some extent on the Continent as well. Outdoor exercise, of varying degrees of violence, became increasingly popular. The early morning dip in cold water became fashionable, and sleep in a bedroom maintained at the lowest possible temperature by open windows was thought to prevent colds and other upsets. The consumption of alcohol, although still heavy, became less excessive, while Victorian prudery replaced the unashamed promiscuity of the Restoration. The cult of the He-Man slowly developed.

What part the Greek ideals played in this revolution, for revolution it was, is another matter. It is extremely doubtful whether they had any direct effect. But the fact remains that there was a return to the Greek doctrine that the healthy individual was more likely to escape disease in general, and infectious disease in particular, than the unhealthy. Conscious efforts were made to produce what is now called positive health.

There is no doubt that this movement did a great deal of good, but it is well that we should remember that there is very little evidence that we can escape much parasitic infection by any particular régime of health. It is possible that the seriously undernourished, or those whose diet is deficient in some of the more important vitamins, may be more susceptible to infection, but it is only when such deficiencies are serious that there is increased susceptibility. It is frequently assumed that the "bohemian" who seldom bathes, takes no exercise whatever, sleeps with a different mistress every night in a room with tight-closed windows, and whose diet consists of equal parts of alcohol and art, is more likely to become a prey to parasites than the upstanding members of cycling clubs, who scour the countryside at week-ends with their lower limbs naked to the winds and their digestive systems full of vitamins. But this is no more than assumption.

When plague or some other devastating pestilence appeared, something more than baths and dieting was obviously required. Various expedients were employed. For many years most of them were designed to enable the individual to evade or neutralize the odours and emanations thought to be responsible. As already mentioned in the preceding chapter, those who were able to do so, usually left the towns and remained in the country until the danger had subsided. But if they were forced to stay at home, Avicenna advised that they should remain indoors, the air being kept warm but without draughts, by the aid of small fans and ventilators. In order to prevent too close contact with telluric emanations, it was inadvisable to sit on the floor, a couch being better. If at all possible, it was best to move to the top stories of high buildings. On other occasions,

however, there was a case for abandoning the open air altogether and going to ground in subterranean caves and dwellings.

A whole battery of neutralizing agents could also be employed. The scent of flowers was considered to be especially valuable and Pero Tafur noted that the Venetians usually walked abroad in the streets armed with large bunches of flowers to protect themselves against the odours which a city built on canals could not very well escape.[2] Englishmen do not appear to have adopted this practice, probably because there were very few flowers for about half the year and, except for the ornamentation of sick-rooms, the principal function of flowers in this country was in the protection of the judicature. There had always been a distressing tendency for judges to be attacked by jail fever or typhus contracted in the course of their duties, from the unfortunate wretches in the dock. Two of the worst episodes of this type had been the black assizes at Oxford in 1577 and at the Old Bailey in 1750. In the latter case the position occupied in the courtroom had been a matter of great importance; the Lord Mayor and those who had sat on his left, together with the Middlesex jury, had been seriously infected whereas the Lord Chief Justice, the Recorder and the London jury, more fortunately placed on his right, had largely escaped. With perils of this nature facing them judges took advantage of all the prophylactic measures available to them, and invariably appeared in court protected by large masses of vegetation. This custom still persists, and if the quantity of blossom has diminished with the years, its continuation suggests that they alone, of all men, still consider that Hippocratic miasmas form one of their occupational hazards.

Other substances besides flowers were also used, all having the common characteristic of a strong odour. Defoe relates how, during the Great Plague of London, the churches were filled with an overpowering mixture of odours, with perfumes in one corner, aromatics in another, and in a third, salts and spirits.

Another and very important standby was fire. It became the practice to purify the air in the streets or inside the houses by some form of combustion. Accordingly, Clement VI spent a large part of the period of the Black Death enduring the sufferings of Phalaris between two large fires which supplemented what one would have considered to be the already adequate heating arrangements of high summer at Avignon. That he survived without catching heat stroke as well as the plague speaks well for his stamina. Two centuries later, in 1563, during the plague epidemic of that year, every householder in London was ordered to lay out wood and make bonfires in the streets and lanes at seven o'clock in the evening on three days of the week. During the Great Plague of London in 1665, enormous bonfires were similarly lit in the streets of the city, their exact positions being recorded with loving care by Defoe. And even so recently as 1832, Exeter saw fit to burn tar barrels in its streets during the cholera epidemic of that year.

More personal prophylactics were also employed. Prominent among them were amulets and similar types of charm. These were popular for many centuries. Most primitive peoples make use of them. Either they were carried on the person, and ranged from gall stones to rings made from coffin nails, or they were set up in the house or village, to which category the ikon and the totem pole belong.

Even so accomplished a physician as Gui de Chauliac recommended a belt of lion skin during the Black Death, and Paracelsus thought highly of the tongues of venomous snakes attached to the person. Others put their faith in hazel nuts filled with mercury, while the sucking of gold coins or, in Germany, plague pennies (adorned with St. Benedict on one side and St. Zacharias on the other) also had their advocates. During the Great Plague of London, it was discovered that by far the most efficient prophylactic was a living toad suspended round the neck in a suitable box. This being somewhat cumbersome, particularly for ladies, a substitute soon became available. This consisted of a dried toad "prepared not long before in as exquisite a manner as possible" and sewn up "in a linnen cloth", which was suspended over the stomach "where after it had remained some hours, became so tumified, distended (as it were blown up) to that bignesse, that it was an object of wonder to those that beheld it". For those who objected to the close proximity of *amphibia* in advanced stages of putrefaction, Dr. Kemp gave a recipe for a non-putrescible protective, which consisted of arsenic, powder of dried toads, sublimate of mercury, flour, dittany, saffron, jacynth and emerald fragments, made into a paste, dried and suspended in a silk bag round the neck.

While practices of this sort were perhaps excusable in ages when medical science was still in its infancy, it is somewhat surprising to learn that onions were carried in Munich during the cholera of 1854 and little bags of camphor by the citizens of Connecticut during the influenza of 1918–19.

The internal application of prophylactic medicines was also not neglected. During plague outbreaks, many employed

alcohol, some going so far in their enthusiasm as to die of delirium tremens. In later centuries, the process of building the British Empire was materially aided by the consumption of large quantities of alcoholic beverages, which not only assuaged the thirst engendered by hot climates but also served to protect the consumer against the manifold diseases to which empire builders are subject. Before this, the most potent preparation seems to have been Venice Treacle or Theriacum, said to have been invented by Andromachus, the physician of Nero, although others attributed it to Antiochus II and some to Mithridates, who combined pharmacology with his duties as King of Pontus in the second century B.C. It was a highly complicated preparation, the recipe listing the flesh of vipers as well as 57 other substances of equally unpleasant origin. With such an extensive formulary, it is hardly surprising that its preparation was very difficult and required great skill. So much was this so that, during the fifteenth century at least, its compounding was quite an event, requiring the presence of the *Priori e Consiglieri* of the Physicians and Pharmacists of Venice. Moreover, it was necessary to allow it to mature in much the same fashion as wine. No one who valued his life took Theriacum which was less than ten years old. It was still widely used in the seventeenth century, and appeared in the German Pharmacopoeia as late as 1882.

During the Great Plague of London, Theriacum was used in large amounts. Defoe mentions that "Others think that Venice Treacle is sufficient of itself to resist the contagion", and evidently was of the same opinion himself, for "several times I took Venice Treacle, had a sound sweat upon it and thought myself as well protected against the infection as anyone could be fortified by the power of

physic". But, its value was evidently beginning to be doubted by some, particularly the Royal College of Physicians, which body recommended a preparation whose active principle consisted of unicorn's horn. The learned Dr. Kemp, who wrote a Brief Treatise on the disease, was, perhaps with some justification, highly sceptical of this official prophylactic, and recommended another of his own concoction, which reads: "Take crab's eyes, one ounce; burnt hartshorn, half an ounce; the black tops of crab's claws, an ounce and a half; make them all into a powder, and take of it one dram in a glass of posset drink when you go to bed, and drink another draught of posset drink after, to wash it down."[3]

Since that time, many other preparations have been advocated for the prevention of infectious disease and, aided by the arts of the advertiser, have found many willing purchasers. But as most of us still suffer from the common infectious diseases in spite of them, it is improbable that, despite the claims of the manufacturers, they are of very much value.

There are, however, other and rather better ways of obtaining immunity. It had been noted during the plague of Justinian that one attack of the disease usually rendered the patient immune to further attacks, and that he was spared if, as occurred in several places, the disease returned. As the centuries passed and the diagnosis and differentiation of disease became gradually more exact, it was found that parasitic infections are roughly divisible into two varieties. One group, of which plague, measles, yellow fever and typhoid are good examples, confers lifelong and very nearly complete immunity on those who survive one attack, while the second group, of which the common cold is a prominent

member, does no such thing. Deliberate exposure to diseases of the first group could therefore be attempted in order to precipitate an attack and so acquire immunity. But the danger of becoming the chief actor in a funeral would be much too great.

Smallpox, which also confers lifelong immunity, is rather a different case. If one takes the precaution of having it when young and in good health, it may not be particularly severe or disfiguring. For this reason, the deliberate exposure of children to cases of active smallpox was not unknown. Now the close proximity of infants of tender years to a case of smallpox in the acute phase is, psychologically at least, inadvisable, and for this reason another and gentler method was employed. This was the artificial production of smallpox by inoculation of pus from a ripe pustule. This method seems to have been of considerable antiquity, for it is referred to in a communication from the School of Salerno, and was widespread amongst the native Africans and Arabs, while the Chinese sometime in remote antiquity adopted the practice of blowing the powdered scabs into the nostrils. Lady Mary Wortley Montagu introduced the method into Europe in 1718.

It was, it must be confessed, a risky business for all concerned. Other diseases might be contracted by these means besides smallpox. The inoculated individual was highly infectious during the illness resulting from the inoculation. Severe crippling infections and even death were not unknown, though some of these disasters may have been due to the severe preparatory treatment considered advisable—"bleeding till the blood was thin; purging till the body was wasted to a skeleton, and starving on a vegetable diet to keep it so". However, it was the best that

could be done all through the eighteenth century, when smallpox was the outstanding infectious disease in Europe now that the plague had slowly moved eastwards.

At various times during the eighteenth century, it was observed in England, France and Germany that an infection of the udder of the cow known as cowpox, or a very similar infection in horses known as grease, might be transmitted accidentally to those in contact with infected animals. The resulting infection was extremely mild, producing merely one or two pustules which came to a head in about two weeks and then died away. There was usually no generalized disturbance to the health of the patient.

There was a strong suspicion amongst farmers and horse copers that people who had had such an infection did not get smallpox if they subsequently came into contact with the disease. Several people, notably Benjamin Jesty, a farmer of the Isle of Purbeck, Mrs. Randall of Whitechurch, and a certain Dr. Nash, deliberately introduced cowpox material into the skin of friends and members of their family to protect them against smallpox. Little notice seems to have been taken of these attempts until Edward Jenner did the same thing in 1795.[4] He did, however, go a step further and showed, firstly, that it was possible to transmit the cowpox material from human being to human being and secondly, that persons treated in this way did not get smallpox, if matter from a smallpox patient was experimentally inoculated into their skins.

Unfortunately, Jenner was temperamentally unsuited to act the part of a pioneer, and it was Drs. Pearson and Woodville, both practising in London, who really created smallpox vaccination as we know it to-day. Fortune had favoured Jenner by providing him with a natural supply

of what we now know to be smallpox virus, whose virulence has been attenuated by passage through the cow. The slight infection produced when the dairymaids of Gloucester infected themselves from the udders of their cows was for all practical purposes an extremely mild attack of smallpox. But it was sufficiently severe to stimulate their antibody apparatus to render them immune not only to further doses of cowpox material but—and this was the important point—to smallpox virus as well.

The principle discovered by Jenner was not forgotten, but the world had to wait some time before any further practical application could come of it. This came in 1880 when Pasteur—impelled somewhat by the rising star of Koch in Berlin—was beginning to study the organisms which cause disease. He had left his wines and beer and silkworms behind him and at 58, and a trifle past his prime, he had turned his attention to the organism which causes chicken cholera. This microbe, which is a close relative of the one which causes plague in human beings, had been seen first by Perroncito in 1878. It grows easily in simple media and kills chickens with unfailing regularity. But Pasteur found that cultures which were old and senile failed to do so. This alone might not have been a very remarkable discovery had he not found, apparently by accident, that chickens which had received the old cultures were immune to fresh and virulent ones. Thus Pasteur had been able, at one stroke, to do that which nature had done in the case of smallpox. He had rendered the chicken cholera organism sufficiently avirulent to be incapable of killing the chickens. But not completely avirulent. It was still able to give them an infection of sufficient severity to stimulate their antibody-forming apparatus and so render them immune. When,

therefore, they were subsequently given fully potent organisms, their antibodies killed the infecting organisms quickly and the chickens survived. He had not only produced artificial attenuation of virulence but proved that infection with such cultures was capable of inducing immunity without harming the individual.

This was a tremendous step forward, and the remainder of Pasteur's life was spent in its exploitation.[5] First anthrax in sheep and then hydrophobia in human beings were attacked and conquered in this way, while Haffkine, a pupil, applied the same principle in an attempt to immunize against cholera in India. More recently, other diseases have been prevented by the same methods. The B.C.G. vaccine used in enormous quantities for the prevention of tuberculosis amongst the war-torn populations of Europe within the past six years, and the 17D strain of yellow fever virus employed for the immunization of millions of people in the tropics, are both living vaccines, attenuated and harmless, but still capable of producing immunity. There is now little doubt of their value.

For a variety of reasons, living vaccines are unsuitable for the prevention of many forms of parasitic infection. But it was soon discovered that dead organisms might act in the same way as living, stimulating the antibody apparatus and so producing immunity. As early as 1878 Toussaint had shown that it was possible to prevent anthrax in this way. But it was Kolle in Germany and Wright in England who produced a practicable method. They found that typhoid fever could be successfully prevented by the injection of two or three doses of typhoid bacilli killed by heat. Although the method had been worked out before the South African War, it was not employed to any great extent

during it, and accordingly the deaths from typhoid fever equalled those caused by the Boers. During the succeeding years, however, it was gradually introduced and was found to be particularly valuable in the army in India, where typhoid had always been endemic. There were only 21 cases with two deaths amongst 5,473 men who had received vaccine whereas there were 187 cases with 26 deaths amongst 6,610 who had not been inoculated.[6] During both world wars, practically all combatants were immunized, and typhoid was a very unusual disease.

A very similar reasoning lies behind another method of immunization, extensively employed for the prevention of diphtheria and tetanus. In these two diseases, the principal factor in the disease process is the secretion of extremely powerful toxins by the growing organisms. It is these substances which damage vital organs and may kill the patient. But two or three injections of toxin (previously rendered non-poisonous by treatment with formalin) will stimulate the antibody-forming apparatus to produce quite large amounts of antitoxin. If, at some time thereafter, these organisms start to multiply in the tissues and excrete toxin, it is immediately neutralized and the patient takes no further harm. This is the basis of the methods nowadays employed for the prevention of diphtheria, and few would deny that it has been extraordinarily successful. Diphtheria is now becoming a very rare disease. The same method was extensively employed for the protection of combatants against tetanus in the recent war, and this very distressing complication of war wounds practically disappeared.

Only a minority of human parasitic infections can be prevented by immunization. There are many good reasons for this, and our best preventive methods are, on the whole,

those which block the path travelled by the organism from donor to recipient.

If measures of this nature failed and parasites were able to break through the defences and produce actual disease, it was impossible, until recently, to do very much to help the patient directly. All that could usually be done was what the medical profession described as "supportive treatment," and the patient, more often than not, had to do his best to cure himself. If he succeeded, some of his cells produced new proteins or antibodies which appeared in quantity in his blood plasma. These can combine with the infecting organisms in such a way as to bring about their destruction while other antibodies neutralize the toxins they produce. Because these antibodies appear about the time the patient begins to show signs of recovery, it is therefore presumed that his recovery is due to them.

These efforts on the part of the patient were, of course, not known about until quite recently. Until then the attempts to treat these infections seem to have been largely misdirected, and some of them were frankly harmful. Because the principal symptom in infections is the fever, considered over many centuries to be due to overheating of the blood, efforts were made to cool the patient. This meant the removal of such large amounts of blood that severe anaemia was probably another hazard to be faced by an already debilitated patient. There was even virtue, it was believed, in the particular day on which the blood was taken, and the particular vein from which it was withdrawn. Strong purges were employed to correct the humours. Patients were put on what was known as a "low diet", its main ingredient a thin gruel. Windows were kept tightly shut to exclude the miasmas supposed to be responsible for

the patient's condition, while the interior of the sick room was rendered horrible by the burning of sulphur or resinous woods to neutralize the miasmas present in whatever fresh air was able to find its way into it. Nothing was known of even the rudiments of nursing or of the value of rest, and it is sad to think that the Prince Consort may well have been hurried to his grave by the fact that when suffering from typhoid he was allowed to get up and lie about on sofas when he should have been flat on his back.

Fortunately for the patient, the drugs employed were probably less dangerous. But they were of very considerable antiquity. In China the *Book of Herbs*, compiled by the Emperor Shang Nung about 3,000 B.C., contained, amongst many others, records of a drug Ch'ang Shang, said to be useful in the treatment of fevers—a claim which modern research has shown to be founded on fact because an active antimalarial alkaloid has been isolated from the drug.[7]

As the years passed, more and more remedies were introduced. Whatever virtue they were thought to possess lay in their ability to correct the humours. Galen, in particular, introduced into the pharmacopoeia large numbers of preparations for this purpose. As there were several hundred of them, the compounding of a prescription was a serious task requiring much care and deliberation. As time went on, bizarre substances such as unicorn's horn, crab's eyes and lizards acquired particular virtues, while Robert Boyle strongly recommended nastier things such as worms, horse dung, human urine and moss from the skull of a dead man. The vegetable kingdom was ransacked, and the great Culpepper had many preparations guaranteed to deal effectively with various forms of infectious disease. Alkanet, for instance, "is as gallant a remedy to drive out smallpox

or measles as any is". But bistort was evidently more certain in its action for "the root in powder form taken in drink, expelleth the venom of the plague, the small pox, measles, purples or any other infectious disease, driving it out by sweating". Tormentil, too, was valuable, and "the juice of the herb or root or the decoction thereof, taken with some Venice treacle, and the person laid to sweat, expells any venom or poison, or the plague, fever or other contagious diseases".

Dog's mercury—to be employed with care because of its poisonous properties—and cow parsnip, were specifically recommended as preservatives from infection. There were also drugs particularly recommended for plague including alehoof or ground ivy, cuckoo pint, pimpernel and thistle, the root being powdered and taken in wine; and fumitory, which also cured "all sorts of scabs, pimples, blotches, wheals and flushes which rise on the face or hands or any other parts of the body".[8]

Such in brief outline were the methods employed over many centuries for the treatment of all sorts of infection. Gui de Chauliac, during the Black Death, admirably summarized it all (it reads better in Latin) "purge with aloetic pills and remove blood by phlebotomy, sweeten the air with fire and comfort the heart with Theriacum, apples and odoriferous substances, console the humours with armenian bole and resist putrefaction with acid substances".[9]

Not all the treatments employed were, however, quite useless. As a result of long continued trial and error, some substances were eventually found, which were undoubtedly of value in parasitic infections. Pliny and Galen employed extract of male fern for tape worms and round worms. This anthelminitic was still used during the Middle Ages.

Then it was dropped, but it seems to have been revived by Valmont de Bomare in 1764 and is still in use to-day. The Romans also employed pomegranate bark for tapeworms, and Dioscorides used santonin for ascaris or roundworm infestation. The North American Indians found, long before the coming of Columbus, that wormseed which contains chenopodium was useful for intestinal worms. The Arabs discovered that mercury ointment was useful in the treatment of scabies.

In all these instances, the parasite which it was hoped to eradicate was large and, even if not visible, its presence as a cause of the symptoms was obvious to all. The value of the treatment employed could therefore be gauged with some accuracy. The first infection due to invisible parasites which was at all affected by treatment was probably trachoma, since there is evidence that copper sulphate was used in Egypt for infections of the eye long before Christ. It was not until the closing years of the fifteenth century that a second parasite of this nature could be attacked with any hope of success. This was the spirochaete of syphilis. Probably because the skin lesions resembled those caused by scabies, mercury ointment or *unguentum saracenicum* became the main specific for this disease. Mercury was also employed as a plaster and as a fumigation. But however it was used, the dose employed was so liberal that mild mercurial poisoning, with loosening of the teeth, ulceration of the gums, and salivation, was the invariable result. To many, the treatment was almost worse than the disease, and it is hardly surprising that guiacum, whose effects are as proportionately kinder to the patient as they are less harmful to the parasite, became much more popular.

The world had to wait another hundred years for the

next example of successful pharmacology. This occurred in 1632, after the conquest of Peru, when the Jesuits discovered that the Peruvians possessed the bark of a tree which could cure the chills and fevers of ague or malaria. This was cinchona or quinine, so named because it cured fever in a certain Countess Chinchon, the wife of the Governor—though modern research has established that while the Governor had two wives in the course of his lifetime, the first died before he went to Peru and the second wife never caught malaria.[10] Quinine was used in all forms of fever, but it is only of value in those due to malaria.

Another substance was added to the pharmacopoeia in the same century, when the root of a South American shrub known as ipecacuanha, which we now know to contain emetine specific for the amoebae of dysentery, was found to be of value for the treatment of chronic diarrhoea.

Chaulmoogra oil, extracted from the fruit of the kalaw tree, was also employed for many centuries in India for the treatment of leprosy. Taken by mouth, its value was doubtful, but when it had been sufficiently purified to be injected, it was found to be considerably more efficacious.

These remedies were probably discovered by accident, but when chemistry finally emerged from mediaeval alchemy, and bacteriology, parasitology and mycology became allied sciences, it was possible to search for remedial substances with a little more certainty of success. Research followed two separate paths.

As soon as it was recognized that in the course of recovery from an acute microbial infection, antibodies appeared in the blood of the patient, efforts were made to produce antibodies in quantity by artificial methods. While it is not possible to do this by chemical methods, it is in some

instances possible to produce these antibodies artificially in horses or other large animals by a long-continued course of injections. The blood serum of such animals after purification and concentration may be of considerable value in the treatment of certain forms of bacterial infection. First used with conspicuous success for the treatment of diphtheria, attempts were made to employ antibodies for the treatment of many other infections, but except for a few diseases, such as pneumonia, they were never of more than doubtful value.

The second line of attack seemed for a time to promise even less success. This was the search for substances which would combine with and kill the parasites without harming the patient. In the case of the larger parasites, such as tape worms, round worms and hookworm, this had already been achieved by the beginning of the present century. But the smaller parasites were not so easy to handle. They are, it is true, easily killed by carbolic acid, corrosive sublimate, and many other chemical substances, but none of these can be used therapeutically because they are extremely poisonous; the patient dies long before the parasite. It seemed likely that the search for chemicals which would kill microbes in the host without killing or injuring him was likely to be protracted, and with the odds heavily weighted against the investigator.

It was Paul Ehrlich who showed that, given *Geld, Geduld, Geschick* and *Geluck* in adequate amounts, the problem could be solved, when he produced an arsenical preparation capable of dealing with the spirochaetes of syphilis, yaws and relapsing fever without serious ill-effects for the patient.[11] This was merely the beginning of a whole series of researches which are still in progress in many laboratories in all parts of the world. As a result, many preparations have now been

produced having specific effects on one or other of the parasites causing disease in human beings. Bayer 205 or Suramin, and the later compounds Synthalin and Pentamidine, have been employed in trypanosomiasis, and Stibophen in bilharzial infection. Then, during the 1930's, came the sulphonamides, which have brought a great many infections within the range of treatment. The antibiotics, penicillin, streptomycin, chloromycetin, aureomycin and terramycin have now gone a long way towards completing the story.

In consequence of all these advances, it is now becoming difficult, given good and adequate treatment, to die of a parasitic infection. Nevertheless, the parasites are not taking all this lying down. They have ways and means of circumventing some of our methods of attack. Employing their ability to undergo mutation or variation, they can, sometimes in a surprisingly short space of time, produce races which are almost, if not completely, resistant to the particular antibiotic or sulphonamide which is being used for the treatment of the patient. This acquired property becomes a permanent characteristic and is carried with the organism if it subsequently produces infection in other people. Fortunately, the susceptibility of the organism to other antibiotics remains unaltered. But there is always danger that owing to the widespread use of different antibiotics, some strains of micro-organisms may, in course of time, become resistant to all the known antibiotics. We cannot afford to be complacent.

CHAPTER SEVEN

PARASITES AND POPULATIONS

Sanitas, sanitatum, omnia sanitas.

DISRAELI, 1872.

THE PRECEDING CHAPTERS have described the various methods which have gradually been evolved by which infectious disease may be controlled or its lethal powers diminished. But different countries suffer from different diseases and have different ideas about the importance of health, and about the prevention and treatment of disease. In discussing the present position in the war between Man and his parasites, it is necessary to bear these variations in mind. Even more so must they be recalled when we come to discuss the future.

In countries with western civilizations, such as those of the European continent and Asiatic Russia, Great Britain, North America and Australasia, a very great deal has, undoubtedly, been done towards the prevention and control of parasitic infection. What differences exist between the countries in this category are slight and conditioned more by variations in local customs, climate or economy, than by ignorance or indifference. For these reasons, the vital statistics—so far as they concern parasitic infections—show a remarkable degree of uniformity not only in their actual levels but also in their trends. In these countries, the diseases caused by parasites fall into four well marked and clearly defined groups.

The first group consists of diseases over whose parasites we still have practically no control whatever, being unable to prevent them attacking us and equally ignorant of how to cure the diseases they produce. Fortunately, there are not many of them, but the group does include the viruses which cause the common cold, influenza, poliomyelitis, encephalitis and infective hepatitis. Cerebrospinal fever must also be included in this group, because we still cannot prevent it, and despite the fact that some forms may be amenable to treatment, there have actually been more deaths from this disease in recent years than before. These then are our failures.

The second group comprises diseases, at one time relatively common, which have now either disappeared altogether or can be completely inhibited if they recur. Leprosy left us, probably by its own volition, centuries ago. Cholera too has gone, but much more recently. It never was an indigenous infection in either Europe or America, but since the great pandemics of the nineteenth century has generally been kept at bay. The severe, crippling form of smallpox was still widespread in the western world as recently as 1870, but the vigorous measures which were instituted about that time have virtually eradicated the disease. As with cholera, there remains, however, a permanent focus of the disease all through the Near, Middle and Far East, and it is only by constant watchfulness that its importation can be prevented.

But it is in the prevention and control of the insect-borne infections that the West has been so successful. Malaria was, at one time, widespread over Europe. It was certainly common in England until about a century ago, but the drainage of marshes has virtually eradicated it except for a

few foci in Essex. Northern Europe is similarly free of it, but it is still prevalent over quite extensive areas of Italy, Corsica and Macedonia, and in the southern part of Asiatic Russia. A great deal has been done of recent years towards its control. Malaria, too, formed one of the hindrances to the colonization of the southern United States, and many accounts could be quoted of the emaciation and languor of the settlers in some areas. Even so recently as 1936, it was estimated that no less than 2,000,000 people in South Carolina, Arkansas, Florida, and Georgia were infected every year. Much has been done towards the eradication of the disease by the Tennessee Valley Authority and the legislatures of the worst afflicted states such as Georgia.

Yellow fever does not appear to have invaded Europe at any time, but there is no doubt of the importance the disease once had in America. About 150 years ago it was widespread over the whole of the eastern United States from as far north as Boston to the Caribbean and the valley of the Amazon. Following the discovery of its mode of transmission by Reed and his volunteers, great efforts were made by the United States to eradicate it by mosquito control and, more recently, by immunization in Brazil. Whether because of these efforts, or because of some other as yet unknown factor, the disease has certainly disappeared. Except for a more or less permanent focus of jungle yellow fever in the forests of the Amazon valley, the disease is now unknown in vast areas of country into which it was the height of folly for a white man to penetrate not much more than a century ago.

The two vermin-borne diseases, typhus and relapsing fever, were very common in Europe until comparatively recent times, but with the provision of adequate supplies

of water and the greater cleanliness of the inhabitants, the louse has suffered a serious setback and with it the diseases which it conveyed. In eastern Europe, however, lice and fleas are still relatively common and, in consequence, typhus and relapsing fever have never entirely disappeared. Under normal circumstances, little harm is done, but when there is war or revolution, their opportunity comes, with consequences we have already related in Chapter III.

Plague disappeared from this country soon after the Great Plague of London in 1665 and from Europe during the eighteenth century. This may have been due to the virtual eradication of the black rat, which is the most important link in the chain of causation of the disease, but other factors such as a diminution in the virulence of the organism may have played an important part as well. The disease never reached America, even at a time when it was widely prevalent in Europe, but it succeeded in gaining a footing after its recrudescence in Hong Kong in 1895. A more or less permanent focus of the disease now persists in the wild mammals of the western states; occasional cases are still detected amongst farmers in these areas.

Other animal diseases transmissible to Man have also gone. Glanders, never very common, disappeared when the motor car replaced the horse as the principal means of locomotion. Rabies has also been controlled by prompt destruction of all infected animals, and the imposition of rigid quarantine on all dogs coming into a country free of the disease. Tapeworms, usually acquired from the meat of infected animals, are also extremely unusual thanks to the strict control now exercised over all meat supplies.

The third group is made up of diseases which were common at one time, and whose causative agents are still

amongst us, but which are now better controlled, so that the actual number of infections is very much less; while, in many instances, the diseases themselves are so amenable to treatment, that death has become less common.

The intestinal infections, such as typhoid and dysentery, are two of the most important diseases in this category. It would be virtually impossible to eradicate them by attempting to remove the infecting organisms from the community which was, at bottom, the method employed for the suppression of the diseases in the second group. There are too many human carriers to render this possible. But with the introduction of the sanitary reforms in the last century, these carriers have now been rendered incapable of harming others. The incidence of these diseases will therefore vary according to the excellence of the sanitary arrangements of the community. While different countries vary considerably in this respect, there is, on the whole, very little intestinal infection of this kind outside tropical countries.

Infections of wounds are in a somewhat similar category. The organisms responsible are much too widespread in Nature for us to attempt their eradication, but it is generally possible to prevent them entering the wound, and of recent years, to cure the resulting infection if they succeed in doing so. About a hundred years ago, practically every wound, whether sustained in war, by accident, or as a result of surgical interference, became infected with pyogenic organisms or those of gas gangrene and tetanus. Much of this was due to ignorance, but hospitals themselves were partly responsible because they formed what were, in effect, permanent reservoirs of infection; the larger the hospital, the larger the reservoir of infection waiting its opportunity. It was accordingly found that in Paris, in hospitals with

more than 600 beds, the mortality rate following operations was as high as 62 per cent. In English hospitals with from 300 to 600 beds it was 41 per cent; with 200 to 300 beds 30 per cent; with 100 to 200 beds 23 per cent; and with 25 to 100 beds 14 per cent. In isolated houses in the country, it was still very high by modern standards, being 10 per cent. With the introduction of antiseptic methods into surgery by Lister, and more recent developments such as asepsis and antitoxin for the prevention of tetanus, this has altered so much that although many modern operations are of a severity and complication undreamed of a hundred years ago, the mortality rate from operations in any hospital is now well under one per cent. Puerperal fever and erysipelas are also, in a sense, wound infections and a combination of preventive measures and chemotherapy has almost swept them away.

To this group belong a number of animal diseases transferable to Man. Anthrax has never been a common disease, but since the discovery of the organism, it has been possible to prevent its transfer to human beings. And the control of dairy herds themselves, combined with pasteurization of milk, have gone a long way towards the virtual eradication of bovine tuberculosis and brucellosis.

In the diseases mentioned above, the technique for their prevention was mostly concerned with blocking the routes by which the organisms reach the patient. With many forms of infection this may not be possible but much can be achieved if by previous immunization the patient is rendered refractory. For various reasons one of the easiest diseases to deal with in this way is diphtheria. During the early 1920's Dr. W. H. Park first began to employ immunization on a large scale for the prevention of diphtheria amongst

the school children of New York. The introduction of toxoid by the Frenchman, Ramon, made this procedure very much safer and, before very long, Ontario in Canada and a number of European countries followed suit. Great Britain was singularly slow in adopting what is, fundamentally, so safe and so efficacious a method, but under the stress of bombing and evacuation it was adopted during the recent war. In consequence, the number of cases of this disease, which had varied from between 43,000 and 73,000 each year from 1925 to 1941, fell precipitously to the astonishingly low figure of only 2,000 in 1949.

The fourth group consists of diseases which we either cannot prevent, or which would require such interference in our private lives as to be impracticable, but which by various methods now available can be rendered less crippling and less lethal. We cannot, for instance, by any known method, immunize ourselves against mumps, chicken-pox, German measles or pneumonia. We may protect ourselves against scarlet fever, but there is no evidence that we can prevent the infection of the throat by the streptococcus which is an essential and, in many respects, the most important aspect of the disease. We could probably prevent the spread of pulmonary tuberculosis and of the venereal diseases, but they would require either financial outlay which is far beyond us, or such interference with the liberty of the subject that we cannot make the attempt.

For one reason or another, therefore, prevention of these infections still eludes us. Their incidence is still high and with some of them quite as high as it has ever been. But of recent years we have been able to inhibit many of the more serious complications which appear in their train. In consequence of this, the death rate from tuberculosis began

to fall as early as 1857, that of scarlet fever fell precipitously during the years following 1871 and those of whooping cough, measles and pneumonia began to fall in 1882, 1896 and 1918 respectively.

It is very improbable that these diseases became less common about the time the death rate began to fall, nor have we satisfactory evidence that the parasites concerned became less virulent. Moreover, the death rates of all of them began to fall long before any very effective methods of treatment were available. How, therefore, has the improvement been achieved? There seems to be little doubt that a whole series of reforms instituted during the nineteenth century were, in the main, responsible. Recovery from all these diseases depends, for the most part, on adequate medical attention, and to a still greater degree, skilled nursing. It is therefore probable that it was the better training of medical students and nurses, and the provision of clean and well-managed hospitals in adequate numbers, which were principally responsible.

There is no doubt that we in the post-war world are very much less troubled by parasites than were our grandfathers or great grandfathers. In consequence, we tend to live longer, and instead of dying of parasitic infection, survive to die of cancer or vascular degeneration. The average age at death, which is also known as the expectation of life at birth, has therefore risen considerably in America and most of Europe over the past century. About 40 years in 1840, it has risen until it is now between 60 and 70. Some countries in Europe, such as Greece, Poland and Bulgaria, lag behind but even in these, the expectation of life at birth varies from 45·9 (for Bulgarian males in 1925–28) to 57·4 (Poland females in 1931–32).[1]

DEATHS IN THE FIRST TWELVE MONTHS OF LIFE PER 1,000 LIVE BIRTHS

British Colonial Empire, 1934–1944	
Cyprus	82
Jamaica	98
Trinidad	109
Uganda	116
Malaya and Straits Settlements	135
Ceylon	135
British Guiana	141
Mauritius	163
Aden	197
Nigeria	250
Zanzibar	295
Hong Kong	327
British India, 1932–1937	173
Calcutta	199
Bombay	201
Karachi	134
Cawnpore	321
China	200
England and Wales, 1944	45
Australia, 1943	36
United States, 1944	40
New Zealand, 1944	30

We must now leave the temperate countries with their higher standards, and turn to the tropics and the East. Although much has been done in certain rather circumscribed areas towards the eradication of many forms of

parasitic infection, there still remains a vast reservoir of human misery in the form of disease, hunger and poverty in India, China, large portions of the African continent, Asia and Central America. In these countries, so far as we know, it is not possible to report much progress. It is true that much has been done in the Philippines, in the Dutch East Indies and in Malaya towards the control of many of the commoner infections. But little has been achieved amongst the two great masses of population in India and China. Here, many of the diseases which the western world expelled or controlled some time ago continue to take a fearful toll.

In India, for instance, cholera occurs year after year, and in an epidemic such as that of 1943 may kill as many as 400,000 in a comparatively limited area. China had 65,000 cases of the disease in 1942. Smallpox is rampant in both countries, 500,000 cases of the disease in China being by no means unusual. The number of attacks of malaria have been estimated at 100,000,000 a year in India and 21,000,000 in China. These three are diseases which may, for want of a better word, be called tropical. When we add to them the parasitic diseases of temperate climates as well, the picture becomes even darker. The number of cases of tuberculosis in India has been estimated at three to nine million, and in China at 35,000,000—or about 8 per cent of the population. It has also been estimated that 10 per cent of the population of China has one or other of the venereal diseases, and no less than one-third have trachoma.[2]

It would take too long to deal, *seriatim*, with other countries in this category, but much may be learned from the Infant Mortality Rate; that is to say, the number of deaths of children during the first twelve months of life. It is usually expressed in terms of 1,000 live births, and is a very good

index of the medical state of a country because young children are the most vulnerable members of the community. The skill and availability of nursing and medical services, the ability of the parents to provide an adequate amount of food, and the severity of the local parasitic diseases, all contribute their share towards determining this figure. It is not always possible to obtain satisfactory statistics for this purpose and for many parts of the world estimates are all that are available: in the accompanying Table, the figures giving the Infant Mortality Rates for a number of areas in the British Colonies, India and China, should be regarded as very approximate.[3]

It is hardly necessary to comment on the figures. They tell their own story. But so many deaths amongst young children will play an important part in producing a low expectation of life at the time of birth. This, during 1929–31, in China, for instance, was 34·85 years for males and 34·63 for females. In British India it was 26·91 years for males and 26·56 for females during 1931.

So much for the present position. What of the future? In the western countries, provided they be spared war, civil strife, invasion, mass bombing, and all the horrors of modern science, such as bacterial warfare, there is no particular reason why control over most forms of parasitic infection should not continue, with a steady gathering in of those diseases which at present elude our control. But what of the East, the tropics, the vast spaces of the world filled with teeming humanity, dominated by small political parties afflicted with extreme nationalism or a local brand of communism? Some of them have already succeeded in throwing off what they describe as the imperialist yoke, while the rest are laying plans for their emancipation,

even if they have not already begun the necessary agitation. What is likely to happen to these countries?

There are, so far as one can see, two obvious alternatives. The first and more probable course of events will be something approaching anarchy in many of these countries. Recently liberated people seldom realize the importance of restraint, there is usually a profusion of mutually destructive liberators, and, in any event, agitators who have lived in fear of their lives for years do not usually make good administrators. Now, anarchy or anything approaching it in a teeming human population is precisely the state of affairs which gives parasites their chance. Their control requires peace, and, particularly in hot climates, abundant resources, skilfully and impartially employed. It is therefore to be expected that, with European control gone, and native rulers in command, the more virulent of the parasites will find a fertile field for their activities.

It is indeed possible that something of this nature may already have started. Whatever their faults as colonial administrators, the Dutch did succeed in controlling most of the more important tropical diseases in their vast Indonesian empire, but now that they have gone, smallpox, plague and other diseases have reappeared, and there is much less control of malaria. There is evidence[4] that Burma is well set on the same course. The Infant Mortality Rate rose from an already high figure of 298 in 1947 to 351 per 1,000 in 1949.

This backward trend may, in time, be checked. In the meanwhile, the apostles of nationalism may reflect that a few million dead of malaria or smallpox are part of the price to be paid for independence. But let there be no mistake about it, unless peace and good government can

be imposed and maintained, Nature will see that the price is paid.

The second alternative could be almost as grim. If a strong central government can maintain control in a tropical country, there is no particular reason why a great deal of the infection now rife should not be prevented or cured. The techniques are all available, and if they have not been applied with quite the vigour with which they were used in the West, this is due, for the most part, to political or economic causes. Given peace and good government, therefore, efforts can be made to improve the lot of the masses in a tropical country. A great sanitary awakening may occur throughout the countries of the Tropics and the Far East. This will result in the survival of a great many of the children who would previously have died. And, as has occurred in Europe and America, the expectation of life at birth will rise.

Other things remaining equal, this can have but one consequence—a considerable increase in the size of the population. Unless, therefore, there is a marked limitation in the size of the Chinese, Indian, Indonesian or Burmese family in the coming years—and age-old religious taboos would have to be overcome first—the population of these countries will increase rather than decrease.

If these countries, particularly India, were able to feed themselves at the present time, there would be little cause for comment, let alone alarm. But there seems little doubt that over 1,000 million people, that is about half the population of the world, are eating less than 2,250 calories a day, when 3,000 is usually considered to be desirable.[5] And it is these undernourished people who are, for the most part, devoid as yet of preventive medicine.

Before long, therefore, the East may be faced with the dilemma that they can save their children from death by parasitic infection but be unable to save them from death by starvation.

The prospect for the future is therefore bleak in the extreme. But whatever is done or not done, parasites will be taking a hand in the proceedings, either by producing more infection than has recently been the case or, if they are are checked and still further inhibited, imposing an almost intolerable strain on the food supplies of the world. How these problems will be solved is another matter; but it is as well that we should realize that they exist.

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many different forms of infection. Malaria was merely a fever, and with many persons, so long as it did not go so far as to kill, was hardly worthy of note. We are, therefore, limited to the more easily recognizable of the human infections. A second difficulty lies in the quality of the medical men who first came into contact with these previously isolated communities. Very few of them had any interest whatever in the diseases of the natives.

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